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SOME MATHEMATICAL ASPECTS OF COSMOLOGY[1]

I. Cosmogony

The intimate relationship between mathematics and astronomy, even in ancient times, is well known; and since the time of Kepler, Galileo and Newton astronomy has been the ideal exact science. From a mathematical point of view, it must be admitted that we have been very fortunate in the fact that the earth is merely one of a family of relatively small planets, and that the earth possesses an extraordinary satellite, so extraordinary that an inhabitant of Mars would doubtless say that the earth and moon is a double planet rather than a planet and satellite. We are fortunate also in the fact that the earth is only 50 per cent. cloud-covered instead of 100 per cent. as may be the case on the planet Venus. Finally, the regular succession of day and night, the waxing and waning of the moon and the annual circuit of the sun among the stars are uniformities in nature that can escape the attention of no one, save perhaps one who lives in a large modern city.

The somewhat less regular motions of the planets with respect to the background of stars excited attention among the ancients and stimulated the search for simple schemes to account for them. Even some slight irregularities in the motions of the sun and moon were discovered more than two thousand years ago, and a scheme of epicycles was invented to account for them, a compounding of uniform circular motions which is the geometrical equivalent of our modern Fourier Series. A dynamical explanation was not sought because it was the age of geometry, and dynamics had not yet been dreamed of. Even Kepler, who devoted a lifetime to the discovery of uniformities in the motion of the planet Mars, and who discovered the three laws of planetary motion which bear his name, did not seek a dynamical explanation of these uniformities. He was content to ascribe them to the intelligence of an angel who guided the planets in their courses. His was the age of spirits, and Kepler's interpretation of uniformities was animistic.

The foundations of dynamics came only with the genius of a Galileo who had little liking for the conceptions of animism. His induction that the natural state of a body was uniform motion in a straight

[1] A symposium lecture read before the American Mathematical Society at its meeting in Chicago, April 10, 1925.

line, and that a departure from that state was due only to force, was one of those great breaks with the past which occur at rare intervals in human history, and which have raised the race of men to its present intellectual level. Galileo initiated a new age, the one in which we ourselves live, the age of dynamics. He was followed quickly by an even greater genius, Newton, who not only completed the foundations of dynamics, but also developed the mathematical concepts which were necessary for progress in the realm of dynamics. Not only was a new mathematical science, coordinate with geometry, brought into being, but mathematics itself was given a forward impetus that seems to gather headway with the passing decades. Furthermore, the consequences are not restricted to the domain of pure intellect; the entire human family is living in a new era. It seems safe to say that the development of the science of dynamics has been the most fruitful and beneficent development in the experience of the race.

The application of the new science of dynamics to the problems of astronomy was immediate. Newton himself was able to show that Kepler's three laws of planetary motion led directly to a law of attraction of the planets towards the sun according to which the force varies inversely as the square of the distance of the planet from the sun; and it required but a slight generalization of this to attain the extraordinarily simple law of gravitation. Newton completely solved the problem of two bodies, and obtained a considerable measure of success in the problem of the motion of the moon. Eclipses and the sudden appearances of comets, that formerly were sources of terror and fright, now fell into the class of orderly and interesting phenomena. Eclipses could be foretold with accuracy, and Halley even dared to predict the return after seventy-five years of the comet which is known by his name.

The differential equations of motion of three or more bodies were first published by Clairaut, who also gave the ten classical integrals of the center of gravity, moments of momenta and energy. Notwithstanding its apparent simplicity from a physical point of view, the complete problem of three bodies has resisted heroic efforts of the most eminent mathematicians from Newton's time to the present day. Regrettable as this may be, it was found possible to develop a mathematical theory of the motions of the planets and satellites of our system, including their mutual actions and reactions, which, for most of the purposes of astronomy, is satisfactory; even the very difficult lunar theory is almost, though not quite, all that could be asked. The brilliant work of Newton, Clairaut, Euler, Lagrange, Laplace, Gauss, Jacobi, Poincaré and many others in the fields of celestial mechanics have erected a monument to the human intellect that can never be forgotten as long as the mathematical faculties of men are active. When we consider the extremely accurate determinations of position that can be made with the telescope, and the very close agreement of theory and observation, it is easy to understand how celestial mechanics has been, and will continue to be, a source of inspiration to workers in every other field of scientific endeavor. It has virtually attained the goal which all other sciences seek, namely, complete and accurate prediction. It should not be forgotten, however, that the reason for this success lies in the extreme simplicity which characterizes our planetary system, together with its almost complete isolation from outside influences.

Indeed this simplicity, together with certain uniformities in the motions of the planets and satellites, led Laplace to depart from the purely mathematical fields, and to speculate upon how all this thing came to be. Whatever be the fate of the ideas which he put forth upon this subject, I can not but feel that this speculation was one of the most valuable things which Laplace did. With certain limitations as to rigor, he had proved the stability of the planetary system, that is to say that the major axes, eccentricities and inclinations of the system fluctuate only within small limits, and in the long run remain unchanged. Mathematically, his conclusions cover the past as well as the future. The system always has been this way and always will be. And yet, forgetting all this, he wondered how the system came to be as it is now. In doing so he recognized the fact, which many experts with mathematical formulae are prone to forget, that not all nature is contained in the differential equations of motion and that the conclusions drawn from these equations are valid only for those periods of time within which nothing extraneous intervenes.

I need not relate that Laplace supposed that our solar system was once a great hot nebula, the boundaries of which extended beyond the orbit of the outermost planet; that by the radiation of its heat into space its size diminished, and therefore, owing to the conservation of angular momentum, it rotated more rapidly; that rings, formed around the equator, were abandoned by the contracting nebulous mass; and that the matter comprising these rings gradually gathered into the more compact and stable form of spheres, and that these spheres now constitute our planetary system. It was a beautiful idea, and it made a very strong appeal to the scientific imagination during the entire nineteenth century. It was simple; even a layman could understand it; it satisfied somewhat our natural curiosity to know the origin of things; and it was sponsored by a great mathematician. What more could be asked?

It must be admitted that ideas with respect to heat

and energy were somewhat hazy in the days of Laplace; and it is indeed very fortunate for celestial mechanics that gravitation is independent of temperature. Shortly after Laplace published his hypothesis of the origin of our family of planets, it was proved by Count Rumford that heat is a mode of motion and therefore a form of energy, and by the middle of the century physicists had put forth the doctrine of the conservation of energy, recognizing clearly that energy exists in many forms which are convertible into one another. The doctrine of the conservation of energy is sometimes called the first law of thermodynamics. There is a second law of thermodynamics which states, in the words of Lord Kelvin, that the energy which is available for useful work always tends towards a minimum; or, in modern terms, that the entropy of an isolated system tends towards a maximum.

These new ideas with respect to energy enabled Helmholtz to make a great contribution to the nebular hypothesis of Laplace. Since gravitational potential energy is convertible into the energy of heat, it was possible to compute how much heat would be developed by a large gaseous mass in contracting from an infinite dispersion to the size of a given sphere as soon as the numerical relationship between ergs and calories was known. This fact was pointed out by Helmholtz in a popular lecture at Königsberg in 1854, a lecture which was translated and printed in the *Philosophical Magazine* of 1856, under the title "On the interaction of natural forces." Helmholtz computed that at the present rate of radiation the supply of the sun's heat thus generated would last for 20,000,000 years. He states that the duration of human history was only 6,000 years, but that the geologists estimated the entire period of organic evolution at from one to nine millions of years. Hence his theory was quite ample for all purposes.

About fifteen years later, Lane[2] and Ritter[3] proved that if the sun is a monatomic gas contracting under the action of gravitation and the radiation of heat, its temperature varies inversely as its radius, and therefore its temperature is increasing. The contributions of Helmholtz and Lane to the nebular hypothesis were very important. They are entirely in harmony with the idea of Laplace; they simplify it by removing the necessity of an initial high temperature and by providing a supply of heat, that, in the middle of the nineteenth century, seemed to be entirely adequate.

The satellite systems of the planets are miniature solar systems. In the case of Saturn and Jupiter the resemblance is striking except for the retrograde motion of the recently discovered outermost satellites. Granted the correctness of the Laplacian hypothesis of the origin of the planets, nothing particularly new was required to explain the origin of the satellite systems. It was necessary only to repeat the process over again. The orbits of the satellites lie very nearly in the plane of the equators of their primaries; their orbits are very nearly circular, and their motion is forward in all the satellites which were known to Laplace. None of them, with one exception, has a mass greater than 1/4000 of its primary, and most of them are much smaller. Among the planets the largest one, Jupiter, has a mass equal to 1/1000 of the mass of the sun, the others being much less.

The exceptional satellite just mentioned is our own moon. Its mass is 1/81 of the mass of the earth, and the inclination of its orbit to the plane of the equator varies from 18.5° to 28.5°. It is much more closely related to the plane of the ecliptic, to which it is inclined only 5°. Its orbit is nearly circular and its motion is forward. From its exceptional character one is tempted to regard the earth-moon system as a double planet. These facts led Sir George Darwin in 1879 to believe that in its origin it had not followed the Laplacian scheme. The planets and other satellites had been formed from a thin shaving taken from the equator of their primary while still in a gaseous condition. Darwin thought that the moon had separated from the earth while in a liquid state, owing to an instability arising from a too high angular velocity, and that after separation from the earth the two bodies continued for a time to rotate as a rigid system about their common center of gravity.

In 1880 Darwin summarized his ideas as to the early history of the moon as follows:[4]

> We begin with a planet not much more than 8,000 miles in diameter, and probably, partly solid, partly fluid, and partly gaseous. This planet is rotating about an axis inclined about 11° or 12° to the normal to the ecliptic, with a period of from 2 to 4 hours, and revolving about the sun with a period not much shorter than our present year.
>
> The rapidity of the planet's rotation causes so great a compression of its figure that it can not continue to exist in an ellipsoidal form with stability; or else it is so nearly unstable that complete instability is induced by the solar tides.
>
> The planet then separates into two masses, the larger being the earth and the smaller the moon. I do not attempt to define the mode of separation, or to say whether the moon was more or less annular. At any rate it must be assumed that the smaller mass became more

[2] J. Homer Lane: "On the theoretical temperature of the sun," *Am. Jour. Sci.* (1870).

[3] Various memoirs in Wiedemann's Annalen (1878–1883).

[4] "Scientific Papers of Sir George H. Darwin," Vol. II, 367.

or less conglomerated, and finally fused into a spheroid—perhaps in consequence of impacts between its constituent meteorites, which were once part of the primeval planet. Up to this point the history is largely speculative, for though we know the limit of stability of a homogeneous mass of rotating liquid, yet it surpasses the power of mathematical analysis to follow the manner of rupture when the limiting velocity of rotation is surpassed.

We now have the earth and moon nearly in contact with one another and rotating nearly as though they were parts of one rigid body. . . .

As the two masses are not rigid, the attraction of each distorts the other; and if they do not move rigorously with the same periodic time, each raises a tide in the other. Also the sun raises tides in both.

In consequence of the frictional resistance to these tidal motions, such a system is dynamically unstable. If the moon had moved orbitally a little faster than the earth rotates she must have fallen back into the earth; thus the existence of the moon compels us to believe that the equilibrium broke down by the moon revolving orbitally a little slower than the earth rotates. Perhaps the actual rupture into two masses was the cause of this slower motion; for if the detached mass retained the same amount of momentum that it had initially, when it formed part of the primeval planet, this would, I think, necessarily be the case.

In consequence of the tidal friction the periodic time of the moon (or the month) increases in length, and that of the earth's rotation (or the day) also increases; but the month increases in length at a very much greater rate than the day.

At some early stage in the history of the system, the moon has conglomerated into a spheroidal form, and has acquired a rotation about an axis nearly parallel with that of the earth.

He continues with an explanation of the effects of the tidal interaction upon the periods of rotation and revolution, upon the eccentricities of the orbit and obliquities of their axes; and states that it has required not less than 54,000,000 years to bring the system to its present state.

It will be noticed that Darwin was somewhat hazy at this time about the mode of separation, but was rather inclined to the idea of a ring which was gathered together to form a spheroidal mass which was just out of contact with the earth, the whole rotating as a rigid system.

Poincaré's attention was attracted towards the problem of the figures of equilibrium of rotating *incompressible* fluid masses and their stabilities by certain theorems which were stated, without proof, in Thomson and Tait's "Natural Philosophy." Poincaré's interest led him to publish a long and extremely interesting paper on the subject in *Acta Mathematica* for 1885.[5] MacLaurin had found in the eighteenth century that a series of oblate spheroids satisfied the conditions of equilibrium, and in 1834 Jacobi had found a series of ellipsoids with three unequal axes which also satisfied the requirements. Poincaré proved that for small angular velocities the MacLaurin spheroids were stable up to the point where they crossed the Jacobi series of ellipsoids. At the point of crossing the stability passes from the MacLaurin series to the Jacobi series. For higher rates of rotation the ellipsoids are stable up to a certain rate, at which the ellipsoids, too, become unstable.

For still higher rates of rotation Poincaré found, by the use of the ellipsoidal harmonics of Lamé, a series of figures which are unsymmetrical, and which were called pear-shaped by Darwin. Poincaré thought he had proved that this new series started out by being stable,[6] but Schwarzschild pointed out in 1896 that Poincaré had made an error in his criterion of stability,[7] which was admitted by Poincaré in 1901,[8] and the question of the stability of those figures was left open.

In the conclusion of his 1885 paper Poincaré said:

> Let us consider a homogeneous, rotating fluid mass, and imagine that this mass contracts, with slow cooling, but in such a way as to remain always homogeneous. Let us suppose that the cooling is sufficiently slow and the internal friction is sufficiently great that the angular rotation remains the same throughout the fluid. Under these conditions the fluid will take always a figure of equilibrium which is stable, and the moment of momentum will be constant.
>
> At the beginning the density will be very small, and the figure of the mass will be an ellipsoid of revolution differing little from a sphere. The cooling will at first increase the flattening of the ellipsoid, which, however, will remain an ellipsoid of revolution. When the flattening has become very nearly equal to 2/5, the ellipsoid will cease to be one of revolution and will become a Jacobi ellipsoid. The cooling continuing, the mass ceases to be ellipsoidal; it becomes unsymmetrical with respect to the yz-plane, and takes the form given in the figure on page 347 (the pear-shaped figure). As we have already observed with respect to this figure, the ellipsoid seems to be compressed slightly around the middle but nearer one end of the major axis than the other; the larger part of the mass tends to approach a spherical form while the smaller part moves towards one end of the major axis as if it sought to detach itself from the larger mass.
>
> It is difficult to state with certainty what will happen if the cooling continues, but it is permissible to suppose that the mass will become creased deeper and deeper, until it is cut through and finally separates into two distinct masses.

5 "Sur l'Équilibre d'une masse fluide animée d'un mouvement de rotation," Acta Mathematica, VII (1885).

6 *Loc. cit.*, 378.

7 K. Schwarzschild, Münchener Inaug. Dissert. (1896).

8 "Sur la stabilité de l'Equilibre des Figures Pyriformes affectées par une Masse Fluide en rotation," Phil. Trans. 196 (1901), 333.

One might try to find in these ideas a confirmation or a refutation of the hypothesis of Laplace, but it must not be forgotten that the conditions are very different, since our mass is homogeneous while the nebula of Laplace was strongly condensed at its center.

It is evident at once that Poincaré's ideas exactly filled the gap in Darwin's theory, which has become known as the "fission theory." That they appealed strongly to Darwin goes without saying, and this interest resulted in a number of papers by Darwin during the succeeding twenty years. His first effort, in 1887, was a study of the figures of equilibrium of two fluid masses revolving as a rigid system. It is evident, if the two masses are far apart and the rate of revolution therefore is slow, that the figures of the masses are prolate spheroids which differ but little from spheres, and that these forms are stable. There are other forms in which the masses are very elongated, but these forms are unstable. They correspond to the very much flattened unstable MacLaurin spheroids.

As the distance between the two masses diminishes, the rate of revolution increases, and the masses become somewhat oval in shape with the small ends of the ovals pointing towards each other. If the two masses are brought close enough together to be touching, Darwin showed that the figures are unstable. Eventually, in 1906,[9] Darwin proved that the stability ceases for two equal masses when the distance between their centers is equal to 2.638 r, r being the radius of the sphere of the combined mass. It is very interesting to compare this value with the limiting distance of stability, 2.45 r, which Roche [10] had found in 1850 for an infinitesimal fluid satellite revolving about a rigid spherical primary. It seems to make little difference whether the mass is nearly all in one of the bodies or whether it is equally divided between the two; the distance of limiting stability is approximately two and one half times the radius of the sphere of the combined mass, and this distance is known as Roche's limit.

In 1901, Darwin attempted to prove the stability of the pear-shaped figures by numerical processes, and his conclusion was that, at least at the beginning of the series, they are almost certainly stable.[11] In 1905, however, Liapounoff[12] announced in St. Petersburg that he had obtained a rigorous solution of the problem and that the pear-shaped figures are unstable. Evidently Darwin did not see Liapounoff's proof, which was published only in abstract, for he found difficulty in accepting his conclusion. The matter was therefore uncertain until Jeans took up the problem in 1915[13] and proved definitely that Liapounoff was correct; Darwin, too, had made a mistake in his criterion of stability. The conclusion therefore seems to be final that there does not exist a continuous series of stable figures of equilibrium which connects the critical Jacobian ellipsoid with the limiting configuration of equilibrium of double masses.

Notwithstanding their instability, Jeans thinks that this pear-shaped series "are of the utmost importance in directing the course of dynamical or cataclysmal motions such as occur when statical evolution is no longer possible."[14] This opinion is somewhat difficult to understand. If a man, walking along a ridge, falls off, his subsequent motions depend very little upon the particular manner in which the ridge continues. The fact that the pear-shaped figures are unstable seems to make them of as little interest as all the other unstable series in this problem.

Jeans has also supposed[15] that the cataclysm which occurs after passing the critical Jacobian ellipsoid may be represented by a jump from the ellipsoidal configuration to the double-mass configuration of the same angular momentum, although he points out that this can occur only if the ratio of the masses is less than one third, since for greater ratios stable double-mass configurations do not exist. Since the moment of momentum of the system remains constant, the amount of this jump, computed on the assumption that the two masses are constrained to be spheres, is as follows:

Ratio of the masses	.3	.2	.1	1/81
Distance between centers (jump)	4.r	7.25r	22r	1047r
Energy of the system	$.5403\frac{M^2}{r}$	$.5178\frac{M}{r}$	$.4765\frac{M^2}{r}$	$.4264\frac{M^2}{r}$

From these figures it is seen that the jump increases rapidly as the ratio of the masses decreases, and the energy of the system also decreases. For the earth-moon system, in which the ratio is 1/81 and r about 4,000 miles, the jump is about 4,000,000 miles, or 16 times the present distance of the moon, and the energy lost in the transformation would be sufficient to heat the entire system some three or four thousand degrees.

It will be observed that there is only one ratio of the masses, about .29, for which both the energy and the angular momentum of the double mass system

[9] Scientific Papers, III, 513.

[10] La Figure d'une Masse fluide soumise à l'attraction d'une Point eloigné, Acad. de Montpelier, I (1850).

[11] *Ibid.*, III, 316.

[12] Sur un Problème de Tchebychef—Memoirs of the Imperial Academy of St. Petersburg, XVII (1905). See, also, Darwin, III, 391.

[13] Phil. Trans. 217 A., also, "Problems of Cosmogony and Stellar Dynamics," 101.

[14] "Problems of Cosmogony," 102.

[15] "Problems of Cosmogony," 134.

agree with the corresponding values of the critical Jacobi ellipsoid, the energy of the Jacobi ellipsoid being .5377 M^2/r. If such a jump occurs it seems certain that the ratio of the masses must lie between 1/4 and 1/3, a small range being necessary to allow for possible thermal changes.

It has been commonly assumed that if a satellite were brought within Roche's limit, that is, two and one half times the radius of the sphere of combined mass, by any means whatever, the satellite would be broken up by tidal stresses and its remains scattered about the primary in the form of a ring. This seems entirely reasonable, and I know of no dissenting opinion. The rings of Saturn apparently furnish an example of the consequences of this process, as the radius of the outermost ring is 2.3 times the radius of the planet, the radius of the nearest satellite on the same scale being 3. In 1859 Clerk Maxwell proved, under certain reasonable assumptions, that such a ring would be stable if its density were small enough.

On the other hand, the fission theory requires us to suppose that after the critical ellipsoid of Jacobi is passed, either the mass separates at once into two parts which jump immediately beyond Roche's limit, or else it separates into many parts which eventually are reunited by their mutual actions into two masses outside of Roche's limit. The jump hypothesis involves the difficulty of radial velocities which would bring the two masses together again in a second cataclysm possibly greater even than the first. If one were compelled to admit, by concrete examples found in nature, that a single mass which becomes unstable through excessive angular momentum does separate into two stable masses, then the second hypothesis would seem to be the more reasonable one, but we should have to admit that we do not see how the thing is done. One can admit that eventually a ring is formed which is composed of small discrete masses, with a total mass and angular momentum sufficiently great to permit the primary mass to become spheroidal, but the satellite state is, at present, beyond us. There is nothing in the astronomical situation, however, which compels us to make such an admission, although Russell thinks the multiple stars are such as would be expected on the hypothesis of fission.[16]

Moulton[17] has made a critical examination of these abstract ideas as applied to the solar system. The celestial bodies are not homogeneous, and it is generally assumed that the density decreases from the center towards the circumference. As MacLaurin pointed out, this fact makes the celestial bodies less oblate than a homogeneous body for a given rate of rotation. Furthermore, we have to deal with a single mass whose angular momentum is constant and whose density is increasing, rather than with a mass whose density is constant and whose angular momentum is increasing. This is important since, if ω is the rate of angular velocity. and ϱ is the density, the eccentricity of the figure of equilibrium depends not upon ω^2 alone but upon the ratio ω^2/ϱ. As the fluid mass radiates its heat and contracts both ω and ϱ increase, in such a way however that ω^2/ϱ slowly increases. Admitting that the process goes on indefinitely, every rotating fluid mass would eventually reach the point where the MacLaurin spheroid branches into the Jacobi ellipsoid. If the earth and moon originally were a single homogeneous mass with the angular momentum of the present system this branch point would not be reached until the density of the mass was 215 times the density of water and its radius something less than one third of the present radius of the earth.[18] As heterogeneity of density only makes the situation worse, the demonstration is complete that the moon did not separate from the earth through rotational instability while the mass was in a liquid state.

So small is the angular momentum of the sun that it will not reach the branching point until it has shrunk to a size in which its equatorial radius is only 11 miles and its period of rotation is 55.4 seconds. The most favorable case in the solar system is Saturn, whose present density is .6 of the density of water and equatorial radius about 37,500 miles. When it reaches the same branch point, its density will be 21 times the density of water and its equatorial radius 14,200 miles; but it will not reach the critical Jacobi ellipsoid until its density is about 95, its longest radius 13,400 miles, and its shortest 4,700 miles. It is evident from these figures, which are due to Moulton, that the fission theory finds no application in the solar system.

As one of the attractive features of the hypothesis of Laplace was that it not only could be appealed to in accounting for the planetary systems, but was also available for explaining the satellite systems, so also is it an attractive feature of the fission hypothesis, which was devised to account for the origin of the moon, that it is also available in accounting for the origin of the binary stars. Aitken states in his book on the binary stars[19] that at least one star in 18, down to the 9th magnitude, is a close double

[16] Russell, H. N., "Origin of binary stars," *Astrophysical Journal* (1910).

[17] See "The tidal and other problems," Publication 107 of the Carnegie Institution of Washington, 79 (1909).

[18] *Loc. cit.*, 151.

[19] "The Binary Stars" (1918), 255.

star visible with the 36-inch Lick telescope. When the spectroscopic binaries are taken into account, however, it is estimated that 40 per cent., or even more, of the stars are double.[20] Here, then, is a great field for the fission hypothesis.

Stars, however, are certainly not incompressible liquids. With respect to the state of their interiors we know nothing at all, but as a mathematical model undoubtedly a compressible gas is much more acceptable than an incompressible liquid; but even a quiescent gas theory may be only a rough first approximation, notwithstanding the theory be mathematically complete, since a star is the most energetic thing we know anything about. The mathematical theory of the gas model, as might be expected, is much more difficult than the theory of the incompressible model[21] and there is little that can be stated that does not rest largely upon conjecture. We are virtually thrown back upon the incompressible liquid for our intuitions. So far as we can depend upon this model, the observations of the binary stars are unfavorable to the fission theory. We have already seen that for this model the ratio of the masses can not exceed one third. But the observations of the binary stars do not harmonize with this ratio.

If the fission theory is to apply to any stars at all it must be to the spectroscopic binaries, since Moulton[22] has shown, and the same results were obtained later by Russell[23] and by Jeans,[24] that after fission has occurred the mutual tidal actions can never separate the two stars very far, so that if the visual binaries were ever formed by fission they were formed while the mass was still in the nebulous state; or perhaps better, the nebulous mass had two centers of condensation from the start, and the theory of fission is not applicable.

Aitken gives a list of 32 spectroscopic binary stars[25] for which the ratios of the masses were known in 1918. In this list there are but two stars for which the ratio is less than one third, and the average ratio for the entire 32 is .748. In the third list of spectroscopic binaries issued by the Lick Observatory[26], which is complete to July 1, 1924, the ratios of the masses are given for 71 stars. There are only four stars in this list for which the ratio of the masses is less than one third, and the average ratio for the 71 stars is .746, which is practically identical with the average of Aitken's list. For 24 of these stars the ratio lies between .9 and 1.0, and for 14 it lies between .8 and .9. It is evident that an approximate equality between the masses is the rule.

It is a fair guess, therefore, that the fission theory does not account for the spectroscopic binaries. It is not applicable to the visual binaries, and it does not fit anywhere within the solar system. I can not, therefore, but differ from Jeans when he states:[27] ". . . a double star must be supposed to be born as a result of cataclysmic motion," that is, by the process of fission; and agree with the opinion expressed by Moulton[28] when he states that his results "are so uniformly contradictory to its implications as to bring it into serious question, if not to compel us to cease to consider it, even as a possibility."

There is no doubt that from the mathematical point of view the theory of fission, as set forth by Poincaré and Darwin, is the most attractive portion of cosmogony. Like so much of his work, Poincaré's paper on the figures of equilibrium of rotating fluid masses is a masterpiece. Darwin's work is not characterized by mathematical brilliancy, but one can hardly read his memoirs on this subject without a feeling of the highest respect for his work. His patience and industry, his honesty and extreme modesty with respect to himself, his thoroughness in the examination of all details, command one's entire confidence, and make one feel that Darwin's attitude towards his problem is a model which should be emulated by all scientific workers who labor in regions in which definite conclusions can not be reached. One turns from this theory with a feeling of profound regret that the evidence seems to be fairly conclusive that, in the birth of the cosmic forms, nature has not followed this model.

During the entire nineteenth century work in cosmogony was entirely in the hands of the mathematicians. Contraction and rotational instability were the central features. During the last two years of the century T. C. Chamberlin[29] entered the field from the domain of geology. With him came a new set of ideas, and a somewhat new mode of treatment.

We do not generally regard geology as a mathematical science, but, notwithstanding this, we can not deny that a competent geologist has a right to cosmogonical opinions. Indeed, a geologist has a closer and more intimate experience with one of the cosmic bodies than either an astronomer or a mathematician, and if he ventures to formulate an opinion in the difficult field of cosmogony the abstract worker

[20] *Loc. cit.*, 274.

[21] See Jean's "Problems of Cosmogony," Chap. VII.

[22] *Loc. cit.*, p. 107.

[23] *Loc. cit.*, p. 191.

[24] *Loc. cit.*, p. 260.

[25] "The Binary Stars," 205.

[26] Lick Observatory Bulletin No. 355.

[27] "Problems of Cosmogony," 252.

[28] *Loc. cit.*, 133. See also p. 160.

[29] T. C. Chamberlin: "An attempt to test the nebular hypothesis by the relations of masses and momenta," *Jour. Geology* (1900).

must listen to his ideas with respect. A pure geologist, however, would be in danger of running amuck in the china closet of dynamics, just as did the philosopher, Kant; and in associating himself with F. R. Moulton,[30] Chamberlin formed a very happy combination of talents that gave promise of being fruitful. To-day no one would think of framing a hypothesis of the origin of the planets without considering very carefully its geological implications. The matter is no longer purely mathematical, nor purely astronomical. It is clearly a mathematical-astronomical-geological problem.

The nebular hypothesis of Laplace had ignored everything outside of our own nebula. It asserted that, once upon a time, the earth was an incandescent liquid mass slightly larger than at present, surrounded by an atmosphere which contained all the water which is at present in the ocean, and therefore 300 times as massive as it is at present. In addition to this it contained all the carbon dioxide which is at present locked up in coal and the sedimentary rocks. These conditions imply a climate, which, geologically speaking, became progressively cooler as the crust of the earth cooled, and the atmosphere was gradually relieved of its excess burden of water and carbon dioxide. Unfortunately, these relations can not be expressed in mathematical formulae; but they are very real for all that, and they must be checked up with the evidence of the rocks.

In the introduction to "The Origin of the Earth," Chamberlin writes:[31]

> But this theory of a simple decline from a fiery origin to a frigid end, from a thick blanket of warm air to a thin sheet of cold nitrogen, consonant with the current cosmogony as it was, logical under the premises postulated, pessimistically attractive in its gruesome forecast, already in possession of the stage, with a good prospect of holding it—this theory of a stupendous descensus none the less encountered some ugly facts as inquiry went on. It seemed to accord well enough with an ice age *if* the ice age came *only* in the later stages of the earth's history, but it was ill suited to explain an ice age in the earlier geological eras. Unfortunately for it, there began to appear signs of ice ages far back in time, and, besides, some of these had their seats much nearer the equator, and, in other respects, were even stranger than the latest great glaciation. The evidence of these later and stranger glaciations was at first quite naturally received with incredulity, but the proof grew steadily stronger with every new test, and the range of evidence was found wider and clearer as exploration advanced. While all this should have weakened, and did weaken, the fundamental concept of great warmth and a rich atmosphere in the earlier ages, while it should have roused skepticism as to the verity of the cosmogony on which it was based, and perhaps did so, still the old thermal concept and the old cosmogony continued to hamper all attempts at a radical revision of glacial theories. . . .
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> . . . In the course of this,[32] still further departures from the generalizations of the inherited view came to notice. Desiccation products were found to be scarcely less abundant and characteristic in the early strata than in the later, and no steady progress from humidity to aridity seemed to mark the progress of time; nor were there found any evidences of even an oscillatory progress from predominant humidity to predominant aridity. If the record favored any generalization it seemed to be that the severest and most prevalent period of aridity fell near the middle of the stratigraphic record.

The implications of the nebular hypothesis are out of harmony with the history of the earth as revealed by the geological record. Moulton found them to be out of harmony also with the present dynamic of the solar system. For example, the present angular momentum of the solar system is less than 1/200 part of the angular momentum which the system must have had when the ring of Neptune was formed, notwithstanding that the elementary principles of dynamics require that the angular momentum of the system shall be constant; the axis of rotation of the sun is 5° out of its proper position; when the ring of Jupiter was formed one tenth of one per cent. of the mass received 96 per cent. of the moment of momentum; some of the satellites of Jupiter have forward motion, some have backward motion; similarly, with respect to the satellites of Saturn; one of the satellites of Mars has a shorter period of revolution than Mars' period of rotation; similarly, the period of the inner ring of Saturn is shorter than Saturn's period of rotation; the high eccentricities and inclinations of the orbits of Mercury and the asteroids are unexpected. There are other objections, but these are enough. It is abundantly evident that the nebular hypothesis of Laplace does not tell the true story of how our planetary system was formed: both astronomy and geology cry out against it and demand that a new story of its birth shall be told. The concept of rotational instability has been tried out in its various aspects during an entire century, and it has been found wanting.

The planetesimal hypothesis[33] of Chamberlin and

[30] F. R. Moulton: "An attempt to test the nebular hypothesis by an appeal to the laws of dynamics," *Astrophysical Jour.* (1900).

[31] Chamberlin, T. C., "The Origin of the Earth," p. 4 (1916).

[32] Chamberlin, T. C., *Op. cit.*, p. 7.

[33] T. C. Chamberlin: "Fundamental Problems of Geology," Year Book No. 3 (1904) of the Carnegie Institution of Washington, p. 195–258, and subsequent issues.

F. R. Moulton: "Evolution of the solar system," *Astrophysical Journal* (1905).

Moulton appeals to another principle, namely, dynamic encounter of the sun with another star. In the zoological world the lowest types of animals multiply by simple division, much as Darwin and Poincaré supposed a rotating liquid mass to do. But in the higher types of life two parents are required in the process of generation; and this is remotely analogous to the generation of the sun's family of planets. It is a bi-parental process.[34] If I remember correctly, it was Lord Kelvin who likened the galaxy to a gas of which the molecules are stars. As in the kinetic theory of gases the collision of the molecules is a fundamental event, so in the dynamics of the galaxy the close approach of two stars is a fundamental event; the time scale in the two cases, of course, is very different. However improbable such an encounter may be for a given star and a given century, nevertheless in the course of time they are inevitable for all stars. If we take a sufficiently large survey of the galaxy we are compelled to face the question: What are the consequences of the close approach, but not collision, of two large, hot, highly active, gaseous masses which are moving on hyperbolic orbits with respect to their common center of gravity?

There are many variable factors in such a situation, and quite likely a great variety of consequences may follow. The problem can be narrowed down somewhat by assuming that the sun had such an encounter some ten or twenty billion years ago, that at the time of the encounter it was in substantially its present condition, and that the distance of closest approach was neither too great nor too small for our purpose, which is, of course, the generation of our planetary system. The first obvious effect is that we have a tidal problem on our hands. On second thought, this tidal problem is complicated with a rotation of the sun about an unknown axis, and at an unknown rate. By the time that we have become adjusted to this idea, it has occurred to us that this is not a quiescent sun, sleek and complacent, but one with a fiery disposition, subject to explosions and great gusts of uncontrollable passion.

I am sure that even such a redoubtable mathematician as Poincaré would have fled precipitately from such a problem, but Chamberlin fortunately is a geologist, accustomed to volcanoes and earthquakes; therefore he stood his ground and prepared to see what would happen. Quite naturally, what he tells us is not couched in mathematical terms, but with Moulton standing guard over the interests of mathematics and dynamics we may be sure that, judged from the point of view of present ideas, the picture presented is essentially correct and sound. If later research and study shows that this is not the correct story, the difficulties, I fancy, will not be perfectly obvious ones.

The planetesimal hypothesis tells us that great tides were raised upon the sun, so that the shape of the sun ceased to be spherical and became somewhat prolate, its longest axis pointing towards the visiting star, but deflected slightly by rotation. The violent ascending and descending convective currents, which are always a normal part of the sun's activities, and which are responsible for or, at least, accompany, the great sun spots and prominences which make the study of the sun so interesting, were greatly stimulated by these vast tides, and were particularly violent in the direction towards and away from the passing star. What are now merely prominences that shoot up a quarter or a half a million miles, only to fall back upon the sun, were then intermittent streams of matter that left the sun with somewhat higher velocities so that some of it doubtless escaped from the sun's control altogether, some of it quickly fell back upon the sun, and some, slightly more than one tenth of one per cent. of the sun's mass, was deflected from its radial motion by the attraction of the visiting star and given an angular momentum about the sun in the same direction as the motion of the visiting star, thereby reducing the eccentricity of the star's orbit.

After the star had passed on its way and the sun had returned to its lonely state, there existed a large amount of matter that had been torn from the sun moving about it in orbits that were in general highly eccentric, and in all of which the motion was forward. Much of this material consisted of free molecules, each of which moved in a Keplerian orbit until that orbit was changed by collision with other molecules; some of it was in large gaseous masses, which are called nuclei, whose gravitative power was sufficiently great to resist the gaseous tendency of expansion and dissipation, and thereby to preserve their identity; and some of it consisted of smaller gaseous masses which could not wholly resist expansion and dissipation, but large enough to delay the process until a certain amount of condensation from the gaseous state to a foggy or a liquid or a solid state had occurred. Thus, in a relatively short time there were large gaseous nuclei, small and smaller liquid masses, very small solid bodies, and free molecules, each pursuing its own path like a tiny planet about the sun—hence the term planetesimals.

Owing to the high eccentricities of the orbits of

Chamberlin and Salisbury: "Geology," Vol. II (1906).
F. R. Moulton: "Introduction to Astronomy" (1906); also (1916).
[34] Chamberlin, T. C., "Origin of the Earth," p. 102.

these planetesimals there was a vast amount of crossing of paths, jostling and collisions. The larger masses gradually absorbed the smaller ones, and, in accordance with well-known principles in celestial mechanics, their orbits became fat and round, and the inclinations of their orbits to the plane of the passing star tended towards zero. In this manner the planets with their nearly circular orbits came into being. Large inclinations and eccentricities are to be expected only in small bodies for which the integration process was small, and it is only in the small bodies that they occur. There are no difficulties with angular momentum, as in the nebular hypothesis; and one can not say that the sun's axis of rotation is 5° out of place. That the axis of rotation of Saturn is 27° out of the perpendicular to its orbit and for the earth and Mars it is 24° out is a blow to the nebular hypothesis, but it causes no disturbance here. The axis of Uranus may be 90° from the perpendicular, and Neptune may rotate backwards without any one being surprised. The fact that there are a thousand asteroids between the orbits of Mars and Jupiter merely tells us that there was no dominant nucleus in this region from the beginning; and the zodiacal light suggests that the process of aggregation is not yet fully completed.

That an eruption from the sun that produced the planetary nuclei also produced one or more smaller nuclei which were travelling at about the same speed seems not unlikely. If at the time of ejection such a system of nuclei were moving like a rigid system in rotation then, if they were not too far apart, they would continue to move as a dynamical unit and the smaller nuclei would move about the planetary nucleus as a system of satellites. Their direction of revolution would be the same as the direction of rotation of the planet and their orbits would lie in the plane of the planets' equator. This sub-hypothesis would account for the uniformity of motion of the larger satellites of the planets Jupiter, Saturn and Uranus. It would not, however, require that the plane of the planet's equator should coincide with the plane of the planet's orbit, nor that it should have any particular relation to the plane of its orbit. Observations on the planets themselves do not indicate that any relationship exists. Thus the inclination of Jupiter's equator is 3° and that of Saturn 27°, while the equators of the earth and Mars have sensibly the same inclination of 23½°. The inclinations of the planes of the orbits of the satellites of Uranus and Neptune are 98° and 145°, respectively; little is known about the planes of equators of the latter two planets.

There is also a possibility that a satellite was captured during the interval of time in which the process of aggregation of the planetesimal material was going on, and this may account for the fact that Jupiter and Saturn have satellites whose motion is retrograde and whose orbits have a high inclination to the plane of the planet's equator. The high inclination of the plane of the moon's orbit to the plane of the earth's equator suggests that the moon, too, is a captured satellite.

I can not, of course, enter into the wealth of details with which Chamberlin and Moulton support the argument for the planetesimal hypothesis. They will be found in Chamberlin's book "The Origin of the Earth," and a series of fifteen articles in the *Journal of Geology,* and in Moulton's "Introduction to Astronomy." To me the arguments are very persuasive, although they are, on the whole, qualitative and not quantitative. They appeal to one who loves nature rather than to one who loves merely mathematics. The planetesimal hypothesis is broad and elastic, capable of admitting much modification without losing its essential character. In this respect it contrasts sharply with the theory of a rotating fluid, incompressible mass, although it has yet to be proven that even this theory is precise after instability sets in.

Jeans has attempted to set up a mathematical model[35] for the planetesimal hypothesis by neglecting the sun's rotation and its violent internal activities, considering only the tidal actions of a quiescent gaseous mass moving in a hyperbolic orbit. But even this simplified problem is too difficult, and the orbital motion has to be eliminated. The results obtained for even this simplified model are valuable and interesting. The model is too inexact, however, to admit of any usable theorems, and in the present state of our mathematical development the naturalistic methods of Chamberlin, checked up mathematically in those places where the theorems of dynamics can be applied rigorously, give far the greater promise of progress. Certainty can not be reached by either method, for the naturalistic methods are not exact quantitatively, and mathematical models are not exact qualitatively. Our hope lies in a judicious combination of the two.

As the matter stands at present, the planetesimal hypothesis of the origin of the planetary system has a clear field, since no other adequate hypothesis is in sight.

W. D. McMillan

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(*To be continued*)

35 "Problems of Cosmogony and Stellar Dynamics." See, also, H. Jeffreys, "The Earth," Cambridge (1924).

THE THIRD PAN-PACIFIC SCIENCE CONGRESS

AN announcement has recently been issued by the National Research Council of Japan concerning plans for the Third Pan-Pacific Science Congress to be held in Tokyo during the period from October 25 to November 18, 1926. It will be recalled that the first of this series of congresses was held in Honolulu in the summer of 1920 under the auspices of the Pan-Pacific Union. The second congress was held in Sydney and Melbourne, Australia, from August 13 to September 3, 1923, under the auspices of the Australian National Research Council. At the Australian congress the invitation was accepted from the Japanese delegation that the congress three years later be held in Japan under the auspices of the Japanese National Research Council, and by action of the Australian Congress the plans for the congress in 1926 are to be in charge of the Japanese Research Council.

At the Australian Congress action was also taken authorizing the formation of a committee to effect a permanent organization of scientific institutions of the various countries of the Pacific region. This organization committee is composed of representatives from Australia, Canada, Chile, France, Great Britain the Hawaiian Islands, Japan, the Netherlands, the Netherland East Indies, New Zealand, the Philippine Islands and the United States of America, the representative from Japan being the chairman of the committee. The purpose of this committee is to draft the constitution and methods of procedure for a permanent international scientific association in the Pacific region and to present this draft to the congress to be held in 1926. The committee has recently been organized. Dr. T. Wayland Vaughan, director of the Scripps Institution for Biological Research and vice-chairman of the Committee on Pacific Investigations of the National Research Council, has been appointed the representative from the United States on this committee, and Dr. Herbert E. Gregory, director of the Bernice Pauahi Bishop Museum of Honolulu, and chairman of the Committee on Pacific Investigations, will represent Hawaii.

The announcement recently issued by the Japanese Research Council states that:

> The main objects of the Third Pan-Pacific Science Congress, like those of the First Congress held in Honolulu, in 1920, or of the Second Congress held in Australia in 1923, are: (1) To initiate and promote cooperation in the study of scientific problems relating to the Pacific region, more particularly those affecting the prosperity and well-being of Pacific peoples, and (2) to strengthen the bonds of peace among Pacific peoples by means of promoting a feeling of brotherhood among the scientists and, through them, among the citizens in general of all the Pacific countries.
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> . . . .
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> As another means of realizing solidarity of feeling and action scientific programs have, for the most part, been arranged in the form of symposia upon selected subjects. Three have been tentatively selected for discussion at General Sessions and sixteen for discussion at Divisional Meetings, as given below, and cooperating scientific institutions are earnestly requested to make suggestions and give assistance in perfecting and carrying out the programs. Some other subjects have been tentatively suggested for discussion at Sectional Meetings and these are also given below. It depends upon what contributions will actually be made, but it is quite possible that some of the subjects will have to be shifted from one of the groups to another, or cancelled or replaced by others.

SYMPOSIAL SUBJECTS TENTATIVELY SELECTED FOR DISCUSSION AT GENERAL SESSIONS

(1) Review of present knowledge of the physical and biological oceanography of the Pacific; tides and currents, temperature, salinity, hydrogen-ion concentration, abundance of plankton, duration of the swimming larval stages of organisms.

(2) Meteorological and time service by radio-transmission in the Pacific region and causes which give rise to its disturbances.

(3) Crustal movements and geotectonics in the Pacific region; earthquake, crust tides, variation of mean sea-level, etc.

DIVISIONAL MEETINGS

A. Division of Physical Sciences

(1) Solar activity in relation to geophysical problems of the Pacific region.

(2) Distribution of terrestrial magnetism in the Pacific region.

(3) Meteorological study of the Pacific region; general circulation of atmosphere, cyclones, correlation of meteorological elements.

(4) History of the strandline of the Pacific during Pleistocene and post-Pleistocene time.

(5) Correlation of the Mesozoic formations of the Pacific region.

(6) Metallogenetic epochs of the Pacific region.

(7) Study of volcanoes in the Pacific region.

(8) Earthquake proof constructions.

B. Division of Biological Sciences

(1) Inter-relationship of the floras of Pacific regions as indicated by the distribution of certain groups of land and marine plants.

(2) Flora and fauna of the islands of the Pacific, with special reference to the problems of endemism and migration.

(3) Different plant successions as observed in various regions of the Pacific.

(4) Scientific bases for plant quarantine in the countries of the Pacific.

(5) Rational methods for the protection of useful aquatic animals of the Pacific.

(6) Genetics in relation to the improvement of important crops, more particularly rice, and of live stock.

(7) Antiquity of man in the Pacific region.

(8) Distribution, prevention and cure of particular diseases among native races of the Pacific region.

Subjects tentatively suggested for discussion at Sectional Meetings are:

Astronomical observations specially connected with the Pacific region.

Report on the network of earthquake observations in the countries of the Pacific.

Transmission of earthquake waves across the Pacific.

Form of geoid in the Pacific region as deduced from geodetic observations, measurements of gravity or plumbline deviation.

Difference of the attenuation of radio waves along and across the meridian of the earth in the Pacific region.

Boundary of the Pliocene and Pleistocene deposits in the Pacific region.

Stratigraphy of the oil-bearing formations in the Pacific region.

Thermal springs in the Pacific region.

Arrangements for information regarding the insect faunas of the Pacific region, especially those affecting economic plants and animals.

Distribution of bonitos and tunnies in the Pacific and their ecological studies.

Origin and development of vegetation on the newer and older volcanic deposits in the Pacific region.

Ecology of the epiphytic flora in the Pacific region.

Rational method of storing cereals.

Distribution of volcanic ashes in the Pacific region and their physical and chemical characters, with special reference to their agricultural value.

Use of green manures in various Pacific regions.

Control and treatment of infectious and parasitary diseases in live stock.

The Ainu people; their origin and affinity with other peoples.

Anthropometry of the races of the Pacific region.

Amoebic dysentery, Anchylostoma (Nector) and Schistosoma: distribution, life-history, clinical aspects, prevention and treatment.

Food, drugs, clothing and dwelling houses in relation to climate in the different regions of the Pacific.

In addition to sessions of the congress and public lectures in connection with it, a number of excursions are planned, including trips to Nikko, Hakone, Kyoto, Nara, Miyajima, Kyushu and Shikoku.

SCIENTIFIC EVENTS

THE GERMAN MUSEUM OF APPLIED SCIENCE[1]

THE Deutsches Museum von Meisterwerken der Naturwissenschaft und Technik at Munich was opened on May 7 with every mark of national rejoicing. The museum, as its name implies, is devoted to applied science, and has for its aim the spread of knowledge of the great discoveries and inventions upon which rest the material civilization of to-day. The festivities commenced on Tuesday, May 5, with a procession of allegorical cars, representing the principal branches of science, through the decorated streets of the city. On the day following the business meeting took place and was attended by ministers, mayors of large cities, leading industrialists, representatives of the Verein deutscher Ingenieure, of the universities, and of some foreign countries; the representative from England was Mr. H. W. Dickinson, of the Science Museum, South Kensington. On May 7 a symbolical play, specially written for the opening by Gerhart Hauptmann, Germany's leading living poet, was performed.

The museum building, commenced in 1906, is an imposing structure, to the designs of Gabriel and Emanuel von Seidl, situated on an island in the river Isar. In plan the building is roughly 100 mm square, and the whole ground floor is occupied by exhibition space, but in the three floors above, a well 60 mm square gives the necessary lighting. The floor space amounts to about 35,000 square meters. At one corner is a tower 64 mm high, and there are three domes devoted to astronomy. The exhibits have been chosen with good judgment. Very great use is made of interiors, and as examples we may mention a scythe forge of 1803 from the Black Forest, the alchemist's laboratory of the middle ages, and a paper-mill of 1708. With these may be classed realistic representations of stone, ore, coal and salt mining situated below the floor level of the museum. Nor must mention of the planetarium in the astronomy section be omitted. By projection apparatus images of the fixed stars, or of the sun, moon and planets, are thrown on a domed ceiling, and their apparent motion over a long period is reviewed in a few minutes. The apparatus has created the keenest interest, and several similar instruments have been ordered; we should like to see such an apparatus set up in Great Britain. The museum is in no sense a state institution, but owes its existence mainly to the labors of Ing. Dr. Oskar von Miller, a well-known electrical engineer, now in his seventy-first year. It is

[1] From *Nature*.

a monument of what can be done by personality, scientific knowledge, ordered imagination and organizing ability, even when interrupted by the war, the subsequent revolution and the inflation of the currency.

STANDARDIZATION OF COLORS FOR TRAFFIC SIGNALS

THE work involved in bringing about national uniformity in the use of colors for traffic signals by the American Engineering Standards Committee is nearing its completion, full agreement having been reached on the various technical details, and the code being about to be published.

The work has been carried out by a sectional committee on which all interested groups are represented, including more than thirty national organizations under the leadership of the American Association of State Highway Officials, the Bureau of Standards and the National Safety Council. The code covers the use of luminous and non-luminous signs and signals in connection with highway traffic, including moving and flashing signals; the use of lights, semaphores and other signaling devices on vehicles.

The three colors agreed upon for primary traffic control signals are: red—for stop; yellow—for caution, and green—to proceed.

The use of red is proper as an indication to stop and to then proceed if conditions are favorable, as for example, when "stop" and "proceed" regulations are in effect.

Yellow is appropriate when caution is to be exercised without stopping, as for partial street obstruction, so as to reserve red for a stop signal.

Green shall be used as an indication to proceed.

The code gives concise qualitative definitions of these three colors as well as of colored glasses and of the colors recommended for non-luminous signs. These recommendations are based on the findings of three subcommittees which collected exhaustive data on the present diversity of highway signals, made a thorough study of the questions relating to visibility of colors and also to sign boards and other non-luminous highway signals.

Careful experiments showed that the red signal lights were most easily distinguished from other colors at a distance and require the lowest light intensity for unmistakable recognition. On the average a red light of 75 candle-power could be identified at 600 feet, while a green light had to be of 250 candle-power, a yellow 750 and a blue light 1,000.

It is of paramount importance that the use or significance of all these signals become so familiar that they will produce an unconscious but correct and effective reaction, as it is doubt in the correctness of signal interpretation that leads to uncertainty in motions and to accidents.

GIFTS TO HARVARD UNIVERSITY

IN addition to the completion of the $10,000,000 campaign for new buildings for chemistry, business administration and the Fogg Art Museum at Harvard University, the following gifts made during the past year have been announced by President Lowell:

Anonymous	$ 100,000.00
Anonymous, for salaries in the Museum of Comparative Zoology	50,000.00
Anonymous, for the construction of Lionel Hall, alongside Holden Chapel	100,000.00
Anonymous, toward the construction of Mower Hall, to complete the gift	30,000.00
Estate of Mrs. William Dorr Boardman for a professorship of Fine Arts	100,000.00
Class of 1904, toward its Twenty-fifth Anniversary Fund	29,000.00
Estate of Joseph R. DeLamar, for the Medical School, additional	350,000.00
Estate of Mrs. F. Gordon Dexter, half to the Medical School and half for books for the Library	167,800.00
Estate of Henry Clay Frick	929,776.33
Dr. Henry Isaiah Dorr, for a chair of anesthetics, additional	30,000.00
Estate of George E. Henry, for the Infantile Paralysis Commission	50,000.00
Estate of David P. Kimball	50,000.00
Mr. and Mrs. George A. McKinlock, an additional payment toward the erection of the fourth Freshman Dormitory, towards which they have already given a large amount, and which is incomplete	58,387.19
Estate of Mrs. William F. Milton, to increase the salaries of professors	715,891.19
Laura Spelman Rockefeller Memorial Foundation for International Research; that is part payment on an agreement to give annually a sum for five years	37,500.00
General Education Board, for a laboratory at the Massachusetts General Hospital, in connection with the Medical School	100,000.00
For salaries, etc.	20,500.00
Herbert N., Jesse Isidor and Percy S. Strauss, a first payment toward the Isidor Strauss Dormitory	75,000.00
Estate of Mrs. William J. Wright, for the Medical School	280,860.19
Sundry other gifts (mostly less than $25,000, but including a gift from Mrs. Charles Chauncy Stillman for the Charles Eliot Norton professorship of poetry) amounting to	1,179,143.16
Alumni gift to establish a fund to be known as the LeBaron Russell Briggs Fund	50,000.00
	$4,517,348.06

THE HOPKINS MARINE STATION

THE Hopkins Marine Station at Pacific Grove has acquired an addition of $50,000 to its endowment through a gift of that amount by the Rockefeller Foundation. The gift will be used to erect a second laboratory building and provide additional equipment. By the terms of the donation Stanford must raise another $50,000 from other sources for the same object, and pending this must spend annually an additional five per cent. of that amount from its own funds for maintenance of the station.

This extension of the facilities of the Hopkins Station will not only promote the science of marine biology and general physiology, but will furnish a very practical aid in the protection and development of the important sea food resources of the Pacific coast. Protection of the sea food supplies depends upon knowledge not only of the fishes, bivalves and crustaceans which furnish human food but also of the sources of supply for these. At the Hopkins Marine Station research is carried on in both these branches. Stanford scientists for several years have been carrying on investigations there and elsewhere of salmon, clams and other important sea food with a view of checking the serious depletion that is taking place.

The Hopkins Marine Station was opened in 1892, the second year of the university's existence, and was named for Timothy Hopkins, trustee of Stanford since the beginning, through whose generosity and interest the original site and buildings were secured and the work there supported through the first twenty-five years. In 1916 the location of the station was changed to a point a half-mile east of the old buildings, where a tract of over eleven acres was secured and a new building erected.

The new situation, consisting of the main portion of Cabrillo Point, insures complete control of the coast line of the point, including an excellent sheltered landing place and harbor for boats of considerable size, and provides room for future expansion. Upon this site the first building of the new station was erected. The building is of reinforced concrete construction. It contains five laboratories available for classes and eight private laboratories for investigators. These private laboratories and all the facilities of the station are open free of charge to scientists from all parts of the country and the world who wish to carry on research in Pacific marine life.

The position of the Hopkins Station, on Monterey Bay, is exceptionally advantageous. It is the point at which the ocean life of the north and the south meet. The marine animals and plants accessible include not only the species found between tide levels, but also those which dwell in the open ocean and those which are secured by dredging at various depths.

The student of land forms finds an equally interesting and in some ways peculiar assemblage of material. This is in part due to an unusual variety of physiographic and climatic conditions within a relatively small area and in part to the presence of a number of characteristic and dominant types such as the Monterey cypress and Monterey pine.

One of the particular advantages of work at the Hopkins Marine Station is the possibility of observing and studying a large number of live animals while these are filling their rôle in the general scheme of marine and terrestrial life.

While the Hopkins Marine Station has always been open the year round for research workers it is only this year that regular class work has been carried on there except during the summer. Now there are courses for undergraduate and graduate students in both the spring and the summer quarters.

SCIENTIFIC NOTES AND NEWS

DR. WARREN K. LEWIS, head of the department of chemical engineering at the Massachusetts Institute of Technology and president of the American Chemical Society, has been elected an honorary member of the British Institution of Chemical Engineers.

PROFESSOR G. H. PARKER, director of the Harvard Zoological Laboratory, has been elected a foreign member of the Linnean Society of London.

THE Laetare medal of Notre Dame University has been awarded to Dr. A. F. Zahm, director of the aerodynamical laboratory of the Navy Department, Washington.

AT the recent Washington meeting of the Association of American Physicians, Dr. Richard P. Strong and Dr. Francis W. Peabody, both of the Harvard Medical School, were elected, respectively, president and secretary.

DR. W. W. KEEN writes that the medal awarded to him by Brown University is the Susan Colver-Rosenberger medal of honor, not "Colvin" as erroneously printed. This medal and the Colver lectures foundation were established by Mr. Rosenberger to honor the memory of his wife, through her father, Colver, who was a graduate of Brown University.

THE honorary degree of doctor of science has been conferred on Clyde William Warburton, director of extension of the U. S. Department of Agriculture, by the Iowa State College, in recognition of his contributions to American agronomy and to the organization of extension agencies.

DR. ALEXANDER BRUNO, former associate director of the Rockefeller Commission to France, has received the degree of M.D. from the University of Paris, which it is said only five Americans have received thus far. Dr. Bruno's thesis was his volume of 500 pages, "The Rôle of the Rockefeller Commission in Organizing against Tuberculosis in France."

DR. BEVERLY DOUGLAS, of Nashville, has been awarded the degree of doctor of science by the Faculty of Medicine of the University of Lyons for his work on the treatment of acute intoxication and infection.

ON the occasion of the King's birthday, Sir John Bland-Sutton, president of the Royal College of Surgeons, was made a baronet, and Dr. J. Robertson, professor of public health in the University of Birmingham, was made a knight.

THE honorary degree of LL.D. has been conferred by St. Andrews University upon Professor F. G. Donnan, professor of inorganic and physical chemistry in the University of London.

DR. ARTHUR H. ESTABROOK was elected president of the Eugenics Research Association at the annual meeting, Cold Spring Harbor, Long Island, on June 27.

WALTER H. FULWEILER, chemical engineer for the United Gas Improvement Company of Philadelphia, was elected president of the American Society for Testing Materials at the twenty-eighth annual meeting held in Atlantic City from June 22 to 26. H. F. Moore, professor of engineering materials at the University of Illinois, was elected vice-president.

PROFESSOR R. HARCOURT, of the Ontario Agricultural College, was elected president of the Canadian Institute of Chemistry at the annual meeting in Guelph, Ontario.

THEODORE STRETTON, of Haslam and Stretton, Ltd., has been elected president of the Association of Mining Engineers of England.

DR. HENRY C. COWLES, professor of plant ecology at the University of Chicago, assumed the chairmanship of the department of botany on July 1, upon the retirement of Professor John M. Coulter.

THE British Air Ministry announces that the Secretary of State for Air has appointed Mr. H. E. Wimperis to be director of scientific research, and Mr. D. R. Pye to be deputy director of scientific research, under the Air Ministry.

DR. JAMES ROBINSON, lately in charge of the wireless research laboratories of the Royal Air Force, England, has tendered his resignation to the Air Ministry in order to take up the post of director of research to the group of periodicals published by the Radio Press.

THE Medical Research Council of England has awarded Rockefeller Medical Fellowships, tenable in the United States during the academic year 1925–26, to the following: Dr. D. Campbell, Pollok lecturer in pharmacology and therapeutics, University of Glasgow; Mr. W. H. Craib, house physician, Guy's Hospital, London; Dr. Katherine H. Coward, assistant in biochemistry, University College, London; Mr. W. S. Dawson, senior assistant, Maudsley Hospital, London; Mr. H. W. Florey, John Lucas Walker Student, University of Cambridge; Mr. A. D. Ritchie, lecturer in physiological chemistry, University of Manchester; Mr. G. P. Wright, Macgregor Student and demonstrator in histology, University College, London.

GÖSTA OKERLOF, of Sweden, who was assistant to Professor Svante Arrhenius, has been granted a Harrison fellowship in chemistry by the trustees of the University of Pennsylvania, to enable him to continue work on the electrochemistry of solution.

OLAF P. JENKINS has resigned as associate professor of economic geology at the State College of Washington and has accepted a permanent position with the Standard Oil Company. He will be stationed at Batavia, Dutch East Indies.

SIDNEY D. WELLS, who has been with the Forest Products Laboratory of Madison, Wisconsin, since 1911, has resigned to take charge of the Paper Mill Laboratories, Inc., of Quincy, Ill.

F. W. SPERR, JR., formerly chief chemist of the Koppers Company Laboratories, has been appointed director of research. He is succeeded by O. O. Malleis as chief chemist and H. J. Rose becomes assistant chief chemist.

DR. J. H. MERRILL, of the department of entomology of the Kansas State Agricultural College, has resigned to take up commercial work in Massachusetts.

DR. GEORGE D. SHEPARDSON, head of the department of electrical engineering at the University of Minnesota, has been granted a sabbatical furlough for the year 1925–1926, which will be spent largely in foreign travel. Professor F. W. Springer will be acting head of the department.

AT Oberlin College leaves of absence for the year 1925–26 have been granted to Professor H. N. Holmes, of the department of chemistry, and Professor Lynds Jones, of the department of animal ecology.

DR. EDWARD HINDLE, Milner research fellow of the London School of Tropical Medicine and Hygiene, has been granted leave of absence for two years to under-

take, in conjunction with Major W. S. Patton, an investigation on the transmission of kala-azar in North China, on behalf of the Royal Society.

CAPTAIN WILKINS, who recently was in Central Australia collecting specimens for the British Museum, has left Adelaide for London to make preparations for his proposed Australian Polar-Pacific expedition. He hopes to take two aeroplanes on his journey and will attempt to fly from the Ross Sea to Graham Land.

CLYDE E. WILLIAMS, superintendent of the Northwest Experiment Station of the Bureau of Mines, Seattle, Wash., has recently returned from Argentine, where he has been studying for the Argentine government the possibility of establishing an iron and steel industry in that country. Mr. Williams is soon to be transferred to the Pittsburgh, Pa., station of the Bureau of Mines.

DR. FRANCIS W. PENNELL, of the Academy of Natural Sciences, Philadelphia, has returned from a botanical collecting trip to Peru, bringing with him approximately 10,000 specimens which are to be divided among the Academy of Natural Sciences, the New York Botanical Garden, the Field Museum in Chicago and the botanical departments of Harvard University.

PROFESSOR ALFONS KLEMENC, holding the chair of chemistry at the University of Vienna, has arrived in the United States for an extended visit. He will assist in editing the International Critical Tables of the National Research Council.

DR. H. P. K. AGERSBORG, Wheeler professor of biology in the James Millikin University, is spending the summer at Yale University, continuing his researches on sensory receptors in nudibranchs.

SIR OLIVER LODGE has been appointed Huxley lecturer for the session 1925–26 at the University of Birmingham. The subject of the lectures will be "Difficulties about the ether."

CARMELIA TOUSSAINT, of the department of mathematics at the College of the City of New York, died on July 17 at the age of forty-four years as a result of being accidentally shot.

DR. SIGMAR STARK, professor of gynecology of the University of Cincinnati, died at Carlsbad, Czecho-Slovakia, on July 15, aged sixty-three years.

DR. WILLIAM PERRY WATSON, former president of the American Pediatric Association and of the New Jersey State Medical Society, died on July 17, aged seventy-three years.

HAROLD H. CLARK, chief engineer of the Wico Electric Company of West Springfield, Mass., and for many years chief electrical engineer of the United States Bureau of Mines at Pittsburgh, has died at the age of fifty-four years.

ALFRED CRAVEN HARRISON, Jr., of Philadelphia and Venice, died July 7, in London, after a brief illness. Mr. Harrison conducted expeditions to the ruins of Copan in Spanish Honduras, Borneo, the Gobi Desert, Mongolia and Siberia.

THE deaths are announced of Dr. D. A. de Jong, professor of pathology at Leyden; Dr. C. Emery, professor emeritus of zoology at Bologna, and Dr. F. Ranwez, professor of pharmacology at Louvain.

PROFESSOR GUSTAV MUELLER, former director of the Astrophysical Observatory at Potsdam, has died.

THE annual meeting of the French Association for the Advancement of Science will be held at Grenoble, July 27 to August 1.

ACCORDING to a press dispatch, the International Conference on Pure and Applied Chemistry, in Bucharest, has accepted an invitation to hold its seventh meeting, in 1926, in the United States in connection with the annual meeting of the American Chemical Society. At a session of the sixth conference held in Bucharest it was voted not to admit former enemy citizens to membership in the International Chemistry Union until the former enemy states are admitted to membership in the League of Nations. The American delegates, under the leadership of Professor James Flack Norris, president of the American Chemical Society, refused to support the motion.

THE summer meeting of the Mathematical Association will be held at Cornell University, on Tuesday and Wednesday, September 8 and 9, in connection with the summer meeting and colloquium of the society. Addresses will be given by Professor G. D. Birkhoff on "The mathematical basis of art" (illustrated); by Mr. H. E. Webb on "The foundations of geometry from an elementary standpoint"; by Professor Irving Fisher on "The mathematics of economics," and by Professor H. L. Rietz on "Certain applications of differential and integral calculus in actuarial science" (retiring presidential address), with probably one other paper. The full program with information as to room and board will be sent to the members of the association about the first of August and reservations can be made at that time through Professor W. A. Hurwitz, of Cornell University.

THE annual meeting of the British Medical Association took place at Bath from July 20 to 25. The president-elect is Dr. F. G. Thomson, of Bath, and the following sections met under the respective presidents: Medicine—President, Lord Dawson of Penn.

Surgery—President, Sir Berkeley Moynihan. Obstetrics and Gynecology—President, Lady Barrett. Pathology and Bacteriology—President, Professor J. C. G. Ledingham. Neurology and Psychological Medicine—President, Sir Maurice Craig. Therapeutics (including Balneology and Radiotherapy)—President, Professor R. B. Wild. Laryngology, Otology and Rhinology—President, Mr. Arthur A. Cheatle.

IN connection with the two hundred and fiftieth anniversary of the founding of the Royal Observatory, Greenwich, and to meet the delegates to the International Astronomical Union, the Royal Society held a conversazione on July 23.

THE Academy of Sciences of Russia will celebrate its bi-centenary at Leningrad and Moscow between September 6 and 14 next. Foreign representatives are being invited.

THE Imperial Mineral Resources Bureau, England, will be amalgamated with the Imperial Institute as from July 1, 1925, and will thereafter be known as the Mineral Resources Department of the Imperial Institute.

DR. HERTZELL has founded at Bremen an institute for research on problems connected with radio and broadcasting. There are accommodations for twenty-five research workers. The main aim of the founder, who is an orthopedist, is to adapt loud speaking devices to medical diagnosis. He calls it the Institut für Radiokunde.

A GIFT has been made by M. Assan Fared Dina to the French Academy of Sciences of an astronomical library and one million francs for astronomical research.

THE late Sir David Salomons, under his will, has left £5,000 to Gonville and Caius College, Cambridge, for extending the college buildings, and £1,000 in augmentation of the Salomons Scholarship Fund to enable the college to give this scholarship more frequently or for longer terms of tenure. To the Royal Institution he left his large magnet (designed by him and known as the Broomhill Magnet), and all the apparatus belonging to it, which enables the magnet to be used as a polariscope and for other purposes. Subject to his widow's interest, he left to the University of Cambridge all his scientific instruments and medical apparatus properly belonging to the workshops or laboratories and theater, his collection of crystals and other apparatus used for polariscope work, etc.

ELI LILLY & COMPANY, of Indianapolis, manufacturers of chemicals and pharmaceuticals, have given a fund of $1,200 a year for a period of five years to the Indiana State University, for research work in this line, to be known as the Eli Lilly & Company fund of the Indiana University.

CHAPTERS of the Pi Mu Epsilon Mathematics Fraternity were established at Hunter College, New York City, and Washington University, St. Louis, Mo., on May 30 and June 4, respectively.

AN X-ray diffraction equipment, by which the crystal structure of matter can be investigated, has been presented to Sir William Bragg of the Faraday Laboratory, of the Royal Institute of Great Britain, by the General Electric Company.

THE French Senate passed a bill on July 8 for the creation of an International Institute for Intellectual Cooperation at Paris, which former Premier Herriot promised the League of Nations that France would undertake.

AT a recent meeting of persons interested in the Peking Union Medical College which is financed by the China Medical Board of the Rockefeller Foundation, an organization called the Yu Wang Fu Association was formed. It was decided that the purpose of the association shall be, by frequent informal meetings, to stimulate good fellowship and to continue and increase interest in the welfare of the college in those who have at any time or in any capacity worked in Peking in connection with it, and have now entered other pursuits. Dr. Franklin C. McLean, the organizer and first director of the college, was elected president; Dr. E. V. Cowdry, secretary-treasurer, and Dr. A. B. Macallum, Dr. Charles Packard and Dr. Donald D. Van Slyke, members of the council. It is planned to establish branches of the association, of which New York is the headquarters, wherever such may be justified, but particularly in Chicago, San Francisco, London, Tokyo and Shanghai. It is proposed to hold the first meeting of the association at the Marine Biological Laboratory, Woods Hole, Massachusetts, on August 1, when an address will be delivered by the secretary of the Rockefeller Foundation, Mr. Edwin R. Embree. Those wishing to join the association are requested to communicate with Dr. E. V. Cowdry, at the Rockefeller Institute, 66th St. and Avenue A, New York, N. Y.

IN accordance with the policy of the federal Bureau of Fisheries of cooperating with the states in fisheries conservation, a biological survey of the marine fisheries of Texas is to be initiated during the present month. The minimum qualification is an A.B. in zoology, and any one interested in securing an appointment should write directly to the Commissioner of Fisheries, Washington, D. C.

THE American Institute of Chemical Engineers, meeting in Providence, adopted the report of the committee on chemical engineering education, recommending that the following fourteen schools be rated as giving satisfactory courses: the Armour Institute, the Carnegie Institute, the Case School of Applied Sciences, Columbia University, the Iowa State College, the Massachusetts Institute of Technology, the Ohio State University, the Brooklyn Polytechnic Institute, Yale University, Rensselaer Polytechnic Institute and the Universities of Cincinnati, Michigan, Minnesota and Wisconsin. It was voted to hold the next convention in December at Cincinnati. The summer session will be at Berlin, N. H.

A CORRESPONDENT writes: "An extended study of aviation hazards with particular reference to life insurance is being undertaken by Dr. Frederick L. Hoffman, consulting statistician, in cooperation with the army and navy services, commercial organizations and air authorities both at home and abroad. The investigation will cover chiefly the post-war period, attempting to establish a trustworthy basis of determining the true hazard of flying and the trend towards greater safety in both military and commercial flying operations. The investigation is the direct result of the suggestion made by Major-General Patrick in his address before the Association of Life Insurance Presidents that the subject should receive more extended and critical consideration. Dr. Hoffman would be pleased to enter into correspondence with any one interested in the questions which will receive consideration. Inquiry should be addressed to him at his office at Wellesley Hills, Mass."

THE Department of Commerce announces that birth rates for 1924 were higher than for 1923 in sixteen of the twenty-five states for which figures for the two years are shown. The highest 1924 birth rate (31.9 per thousand population) was in the rural districts of North Carolina, and the lowest (14.9) in the rural districts of Montana. Death rates for 1924 were lower than for 1923 in twenty-three of twenty-nine states shown for both years. Record low rates appear for Connecticut, Delaware, Kansas, Kentucky, Maine, Massachusetts, Montana, Nebraska, Ohio, Pennsylvania, Vermont, Virginia and Wisconsin. The states having higher death rates for 1924 than for 1923 are California, Florida, Mississippi, Oregon, South Carolina and Washington. The highest 1924 death rate (22.1 per thousand population) was in the urban districts of Mississippi, and the lowest (6.5) in the rural districts of Montana. Infant mortality rates for 1924 are generally lower than those for 1923; only three of the twenty-five states show higher rates in 1924. The highest 1924 infant mortality rate (121.6) was in the urban districts of South Carolina, and the lowest (51) in the rural districts of Nebraska. Infant mortality rates are shown for both years for forty-four cities of 100,000 population or more in 1920. For thirty-six of these cities the 1924 infant mortality rates are lower than those of the previous year. The highest 1924 rate (92) is for Trenton, N. J., and the lowest (45.3) for Seattle.

WE learn from the *Electrical World* that in concert with the under secretary for technical education and the University of Lille, France, there has been founded in that city an electromechanical institute. It occupies the former building of the Institut des Arts et Métiers and thus has at its disposition an important equipment of machinery and tools. It also will be able to make use of the laboratories of the faculty of arts and sciences. Organized on entirely original lines, its program of instruction will be such that both the student and the industry will have advantages hitherto unknown in France. The instruction will supplement both ordinary engineering and electric science with a dual (or cooperative) course which will permit a student once enrolled to take charge of actual installations of electric power production or application. The length of this supplementary course is reduced to the minimum of six months for students already in possession of that general knowledge which would presumably permit their passing the ordinary mechanical examinations. Thus at a minimum expenditure of time and money they are fitted for immediate employment in the higher positions which at the present time it is difficult to fill because of a dearth of competent men. Various electric companies are giving encouragement and financial assistance to the project, which within the course of the next few years may be expected to furnish to them the technical personnel which the continually increasing number of central and distributing stations require.

UNDER the terms of an order issued with the approval of President Coolidge and effective July 1, supervision of lands bearing oil segregated for the use of the navy will be conducted in the future by the Geological Survey instead of the Bureau of Mines as formerly. A new organization unit, to be known as the "conservation branch," will absorb the functions heretofore exercised by the Bureau of Mines in naval oil reserve administration. The survey, through the branch just created, also will take over the proposed naval oil reserve in Northern Alaska, covering an area of 50,000 square miles. In his announcement on the "conservation branch," Secretary Work said that the new unit would have engineering control of all mineral leasing on the public domain as well as the classification of public lands.

THE Association to Aid Scientific Research by Women has renewed its support of the Zoological Station at Naples, suspended since 1917, and, for the season of 1925, has appointed Mrs. Mary Mitchell Moore (Bryn Mawr, '15), wife of Dr. William E. Moore, of Rutgers College, as its "scholar." The association contributed for nineteen years, beginning in 1898, to the support of the American Women's Table at Naples.

UNIVERSITY AND EDUCATIONAL NOTES

WASHINGTON UNIVERSITY, St. Louis, has announced a gift of $1,000,000 from Charles Rebstock.

JOHN D. ROCKEFELLER, Jr., has contributed $1,000,000 for endowment of the Divinity School of the University of Chicago.

THE sum of $50,000 has been given to the Johns Hopkins University by James Speyer, of New York, to establish a lectureship fund to bring scientific men to the university from Germany.

A REGULAR four-year medical course, leading to the degree M.D., has been established by the University of Wisconsin. Hitherto the first two years only have been offered.

STANFORD UNIVERSITY has organized a school of engineering, combining the work of all its engineering departments in a four-year undergraduate course leading to the professional degree of engineer. The new school will begin functioning at the opening of the next college year in October. Professor Theodore J. Hoover, at present head of the department of mining and metallurgy at the university, is to be the dean.

DR. HELEN P. WOOLLEY, psychologist of the Merrill-Palmer School, Detroit, has been appointed director of the Institute of Child Welfare Research and professor of education, with a seat in the faculty of Teachers College, Columbia University.

DR. E. F. MALONE has been appointed Francis Brunning professor of anatomy at the University of Cincinnati.

DR. HENRY BLUMBERG, of the University of Illinois, has been appointed professor of mathematics at the Ohio State University.

DR. EARL B. MCKINLEY, national research fellow in medicine with Professor Bordet at the University of Brussels, has been appointed as assistant professor of bacteriology in the College of Physicians and Surgeons, Columbia University.

DR. THOMAS D. HOWE, Ph. D. (Wisconsin, '25), has been appointed instructor in biology at the James Millikin University.

DR. IVAN C. HALL, professor of bacteriology in the New York State College of Agriculture at Cornell University, has become head of the department of bacteriology and public health in the new University of Colorado Medical School at Denver.

DR. WILLIAM W. CORT, associate professor of helminthology, department of medical zoology, School of Hygiene and Public Health, the Johns Hopkins University, has been promoted to a professorship of helminthology.

DR. ARTHUR W. WRIGHT, of the Boston City Hospital, Boston, has been appointed assistant professor of pathology at the Vanderbilt University Medical School at Nashville.

DR. HIBBERT WINSLOW HILL, London, Ont., has been appointed professor of bacteriology and professor of nursing and public health at the University of British Columbia, to succeed the late Dr. R. Mullin.

AT the University of Cambridge, D. Keilin, Magdalene College, has been appointed university lecturer in parasitology and J. A. Carroll, Sidney Sussex College, assistant director of the Solar Physics Observatory, has been appointed university lecturer in astrophysics.

DISCUSSION AND CORRESPONDENCE

THE ART OF PLUVICULTURE

IT is remarkable, when we consider the varied attempts in our country to grow rich without risk or effort, that one of the most certain enterprises of this sort has been almost completely overlooked by trade-schools, as well as by the argus-eyed press.

The professions of crystal-gazing, clairvoyance, kleptomania, and the like, receive due attention from the press, as well as by the police, all efforts to benefit humanity by these means being everywhere discouraged. The ancient arts of astrology and horoscopy, however, have their quarter-column in most of our leading papers, while the modern diversions of pluviculture, chiropractics and hormonism are everywhere treated with respect.

Of these none can be more scientific than is pluviculture or rainmaking, as it is commonly called. Yet nowhere so far as I have noticed is the method of operation made clear, nor the economic laws which make it, not only valuable to the farmers, but a sure thing in general. Even the astute Father Ricard goes on with his prophecies, apparently oblivious to the work of other scientists right within the range of his storms and sun spots.

For successful rain-making, it is necessary to find first a region in which rain is expected but has failed to come. The first element is then to find a few

hundred ranchers willing to give, let us say $8,000 to ensure a storm, worth easily let us say $50,000 to them.

The pluviculturist has next to build a modest shack or to set up a tent for his chemical operations. Next he prepares certain chemicals in accordance with a secret formula. These may cost $50 more or less, according to the likelihood of further demands for extension of his operations. What the formula is, naturally no one has explained. Let me suggest a formula of my own. Take first ten pounds of pulverized chlorate of potash, and an equal amount of granular cane sugar. Mix these carefully in a wooden tub and when ready pour over them a liter (or pint) of sulphuric acid (c. p.). This simple and inexpensive preparation will produce surprising results. These may be brilliantly enhanced by using a pound of magnesium ribbon, to one end of which a lighted match has been applied, the whole sent into the air by attachment to a sky-rocket. This is most effective towards night or after clouds begin to form. Then certain salts of strontium yielding red light, barium yielding green, and other salts yielding lights of different colors, should be set on fire. That this formula of mine has been used by any professional rain-maker, I do not know. I am sure that any pharmacist might furnish something equally good. Some also use an old-fashioned fanning mill to condense the air, but that is less impressive.

Now that the chemistry has been provided for, the most important point follows, the economics of the process. There is an international institution known as "Lloyds" which insures anybody against anything, after a study statistical or meteorological of the chances. It charges a modest premium which naturally varies with the probabilities. If you want a clear day for a picnic, or a football game, Lloyds will for a consideration insure you against rain. Lloyds do not control the weather, but while losing the premium charged you will receive enough to finance your pleasure or your sport next time. You can insure a base-ball player against striking out, or an airship from falling into the sea, in accordance with scientifically accepted probabilities. Every well-regulated stadium or other center of culture is a client of Lloyds.

Now let the rain-maker insure himself against a rain-less day. I do not know the premium which Lloyds would charge. In California it would vary, being relatively low in March, especially in the north, rising higher to one hundred per cent. or even more in July.

Let us suppose that a dry period should occur in March, the month of all months when rain is most desired in Coarse Gold, let us say, in Alcalde, and in Calexico. Let us take a high estimate, assuming that the premium charged is $2,000, on amount of insurance in case of a dry day being $8,000. The balance sheet of rain-making is shown below:

A. In case of rain

Received from the people of Alcalde	$8,000
Paid for chemicals and housing	50
Paid for premium to Lloyds	2,000
Balance of profit	$5,950

B. In case of no rain

Received from Lloyds	$8,000
Paid for chemicals and housing	50
Paid for premium to Lloyds	2,000
Balance of profit	$5,950

C. In A: case of rain

The people of Alcalde pay $8,000, and receive rain worth $50,000.

D. In B: case of no rain

The people of Alcalde pay out nothing and receive nothing. They are then ready to try again. The transaction thus involves therefore no loss to anyone except to Lloyds in case of B. And this great corporation knows how to recuperate elsewhere. But under A, of course, the people of Alcalde would have had their rain anyhow.

There is one element of risk. Once in San Diego County and once again in Fresno County the rain came as a desolating deluge, doing much damage and relatively very little good. It is said that under these conditions the cautious pluviculturist saw fit to take no chances and never collected his fee.

It was Barnum, was it not, who stated the lesson to be drawn: "A sucker is born every hour." Herbert Spencer insisted that "to save men from the consequences of their folly would fill the world with fools."

For this reason perhaps the press discourages crystal-gazing and applauds the pluviculturist.

David Starr Jordan

A ROOT ROT OF ALFALFA

Many fields of alfalfa throughout the state of Colorado during the past year have exhibited a dying out due to a root rot.

The disease first manifests itself on plants three or more years old as a flagging of the shoots in the spring. These shoots remain wilted for some time, irrespective of moisture conditions, and eventually die and are not replaced. Sections of roots of affected plants reveal a plugging of the vascular system with

a yellow substance giving a characteristic test for wound gum. This plugging is progressive.

The diseased roots on the average are able to transport but one fourth the amount of water carried by healthy roots, as determined by pumping water through lengths of diseased and healthy roots. It is interesting to note that diseased roots contain little if any stored starch, while healthy roots are rich in that substance. The result of this lack of food supply is poor growth in the spring and a progressive weakened condition. Isolations from deep-seated diseased tissue constantly yield a fluorescent bacterium. Inoculations with this organism by root-cutting and injection into the roots cause discolorations and plugging of the vascular system identical with field symptoms. Check inoculations with water, physiological salt solution and other bacterial organisms isolated from rotted crowns failed to react in this way.

L. W. DURRELL
W. G. SACKETT
COLORADO AGRICULTURAL EXPERIMENT STATION

THE DEFINITION OF LOESS

THE excellent summary with reference to the "Origin of the loess of the Palouse Region, Washington," given in SCIENCE of May the first, 1925, page 469, raises again the question of the proper use of the term loess. Is a deposit in a lake properly a loess?

As Grabau[1] briefly describes recent deposits of loess, they are chiefly wind laid deposits, may contain beds laid down in shallow water and may even contain beds of sand and gravel washed in by streams. He uses the term silt[2] in describing the size of the particles apparently as the word is used in soil surveys.

The present writer believes it is time to use the name loess with a definite meaning: a wind-laid deposit of loosely arranged, angular particles of calcareous silt loam typically intermediate in fineness between sand and clay, of uniform mechanical composition, often with color changes revealing faint lamination, and with a tendency to break off in vertical slabs.[3] This accords with the general use of the term. With the loess may be associated sheets of gravel which are not loess, but water laid. With it may also be associated beds of water-laid silt with shells of fresh-water molluscs. With it also may be associated a glacial boulder, but this boulder, though on the loess and surrounded by loess, is not loessial.

Failure to make such distinctions has been the occasion of misunderstandings in the past. The loess along Missouri River was in the early days thought to be a lake deposit. Later it was recognized as a wind-laid deposit with all the peculiarities of such a deposit. Later still, patches of silt laid down elsewhere in sheets of water in loessial areas and containing fresh-water instead of air-breathing molluscs were spoken of as if loess. It is well to distinguish between these classes of deposits and to use distinctive terms.

In describing any deposit we may recognize the source from which the material was derived, but the later deposit does not retain as its name the name of the material from which it was derived. A bed of sea sand is a marine deposit of sand regardless of the crystalline rock from which the sand was originally derived, and it is a marine deposit regardless of the agencies of river action that may have been involved in transportation. The fine deposits laid down by the wind are loess, regardless of the source of the material from which that loess was derived. It may have come from weathering of ancient rock, it may have come from soil or from alluvium along a recent river, but when laid down by the wind it is loess. When washed out later and laid down in water by a river it becomes a river silt (alluvium if on a flood plain). When laid down in the quiet waters of a lake it becomes a lake silt, along with such portions as may have been transported to that lake by streams, whatever the source of that fine material. Often one may be uncertain as to whether a given bed is a true loess. Then suitable terms should be used and the bed described accordingly.

If the term loess is thus confined to fine wind-laid deposits, as described, the term will have a definite meaning, which will accord with the general significance of the term.

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[1] A. W. Grabau, "Principles of Stratigraphy," pp. 565–568.

[2] *Idem.*, p. 565.

[3] Varied from Grabau, *idem*, p. 565.

QUOTATIONS

WHAT IS REASON FOR?

ABOUT sixty years ago Huxley made his famous answer to a precursor of Mr. Bryan. Wilberforce, Bishop of Oxford, had appeared before the British Association for the Advancement of Science and in the manner of Mr. Bryan congratulated himself that he was not descended from a monkey. Darwin himself was absent on account of illness, but Huxley was in the hall, and when Wilberforce had finished he rose and said in substance the following:

> If I had to choose, I would prefer to be a descendant of a humble monkey rather than of a man who employs his knowledge and eloquence in misrepresentation of those who are wearing out their lives in the search for truth.

Ostensibly the purpose of Mr. Bryan's outpouring of idiotic contempt for science and learning was to assert the glory of man, to prove that he came "from above" and is created in the image of God. We have never read a more blasphemous speech than Mr. Bryan's. For the whole purport of it was to hold up to ridicule and contempt, to discredit and malign, the one achievement of man that most clearly distinguishes him from all the rest of the animal kingdom. For surely if man is distinct from the other animals the distinction lies in his creation of science, in his power to extend his understanding of the universe. Mr. Bryan cries out that the wicked scientists are robbing man of his sublime ancestry. Mr. Bryan is robbing man of all sublimity now. For when, pray, does man rise to a greater dignity than when a Copernicus, a Newton, a Darwin or an Einstein makes some part of the universe intelligible? Has man a greater dignity when he makes political speeches for big fees and plays upon the fears of the ignorant?

The assumption that righteousness as well as divinity is a monopoly of Mr. Bryan's fundamentalist friends is an impudent conceit. Mr. Bryan talks as if he, for example, were a better man, better morally, than the scientists upon whom he pours his contempt. They won't answer him, but the answer can and should be made for them. The answer is this: to contribute successfully to the progress of science requires more integrity of mind, more purity of heart, more unselfishness, more devotion, more unworldliness, than any other kind of human activity. The work is harder, the standards are higher, the discipline is more rigorous, than men like Mr. Bryan have ever dreamed of demanding of themselves.

There are quacks and knaves among scientists, to be sure, but among the men who are really doing the work of science a moral code exists and is followed which would put the rest of us to shame. The search for truth. That is a simple phrase, but the labor, the care, the patience and the exactness which it requires are something beyond the comprehension of a man who has lived by flamboyant speeches. Has Mr. Bryan ever conceived, while he was on the Chautauqua as Secretary of State, or selling real estate in Florida, the quality of soul that is needed to induce a man to work thirty years over a microscope and then give his results, without a penny for himself, to all mankind?

The whole thing is beyond his ken. But at least he might be silent in the presence of men who are doing, if any men are doing it, the work God gave men brains to do. God did not make the human reason solely for use on the lecture platform. If the human reason has any purpose which may be called divine, that purpose is the full, free and fearless use of reason to understand the mysteries of the universe. —*The New York World.*

SCIENTIFIC BOOKS

Interfacial Forces and Phenomena in Physiology. By Sir William M. Bayliss. E. P. Dutton & Co., New York, 1923. 196 pages.

With the advance in our knowledge of the processes of living matter has come an increasing appreciation of the degree to which the underlying chemical reactions are controlled by the special physical structure of the protoplasmic system. Perhaps the most remarkable feature of the reactions determining the response of an irritable cell to stimulation is their susceptibility to electrical control; with this is associated a special sensitivity to the presence of surface-active compounds of all kinds. The general significance of these facts and their bearing on the problem of the structure of protoplasm have only recently been appreciated. Electrical sensitivity and narcotizability are universal properties of protoplasm.[1] These properties, however, are clearly based on surface-processes—the former depending on changes in the electrical polarization of interfaces (as Nernst first showed), and the latter on the displacement of reactive compounds from the protoplasmic surfaces (see especially Otto Warburg's recent work). The dependence of the metabolic reactions on protoplasmic structure thus appears to be essentially a consequence of their dependence on surface-conditions. Protoplasm is a colloidal system, bounded and partitioned by films with diffusion-proof or semi-permeable properties; hence it is a system in which the phenomena characteristic of surfaces or interfaces are exhibited in a highly developed form. Irritability, contractility, electrical and chemical sensitivity, distance-action (transmissivity) are now seen to be expressions of this all-pervading rôle of surface-forces in protoplasmic activity. There is also every indication that normal growth (which is similarly electrically sensitive and narcotizable) is based primarily on the deposition of structure-forming material at the protoplasmic interfaces. This view implies that a concentration or deposition under the influence of surface forces, in other words a process of adsorption (which is essentially oriented attachment of molecules to surfaces), plays a controlling part in the formation of new organized structure; at least it is difficult to conceive of any other physical means of securing the necessary structural regularity.

The manner in which chemical reactions in polyphasic systems are influenced by the special conditions at the phase-boundaries is evidently a subject of

[1] This was recognized by Claude Bernard in his "Leçons sur les phénomènes de la vie," and elsewhere.

fundamental physiological interest; and it is only natural that the chief treatise in this field, Freundlich's "Kapillarchemie," should devote much space to physiological considerations. Sir William Bayliss' little book gives a highly interesting and individual—if necessarily incomplete—account of the physiological importance of interfacial phenomena. He characterizes protoplasm as "a heterogeneous system of many phases, solid and liquid, separated by membranes of whose internal arrangement little is known"; and he favors a conception of "ultra-microscopic reaction-chambers, bounded by reversible semipermeable membranes." In the first four chapters (occupying more than half of the book) he reviews briefly heterogeneous systems, surface-tension, adsorption and colloids. The importance of adsorption is especially insisted upon; the influence of electrolytes and of surface-charge on adsorption, chemical effects dependent on adsorption, the influence of the accompanying orientation on the reactivity of the adsorbed molecules and the rôle of adsorption in enzyme processes are considered in some detail.

Bayliss regards adsorption as a chief factor in the behavior of all colloidal systems; accordingly he deprecates the neglect of all but purely chemical considerations in the treatment of the colloidal behavior of proteins. To him the distinction between "classical" and "colloidal" chemistry is an imaginary one; naturally the chemical behavior of proteins is in accordance with their amino-acid constitution; but in addition they exhibit characteristic physical features of behavior which can only be explained by reference to adsorption and variation in state of aggregation. The characteristic lyotropic series (Hofmeister series) are the expression of such factors, which are superposed on the purely chemical. The problem of the hemoglobin-oxygen equilibria is discussed briefly in a separate chapter; Bayliss believes that the heterogeneous character of the system has been insufficiently considered, and that this may account in part for the anomalies in its chemical behavior.

There is an interesting brief discussion (pp. 124 ff.) of the possible rôle of adsorption in the metabolic reactions of protoplasm and especially in synthesis. Orientation of molecules at the protoplasmic interfaces may be a means of bringing reactive groups into conjunction. If water is less adsorbed than the interacting molecules it may be displaced from the surfaces; regions relatively free from water may thus originate, and the conditions for dehydrolytic synthesis (*e.g.*, of esters) be furnished. The need for a low concentration of water at the site of many syntheses, including that of protein, is apparent. Here it may be recalled that in many unfertilized egg-cells a temporary dehydration (by hypertonic sea-water) is an essential condition for the artificial initiation of development, a process evidently based on the synthesis of new structure-forming compounds.

The properties of plasma membranes are considered briefly, and the problem of varying permeability, with its relations to the bioelectric processes and stimulation, is reviewed. A brief but suggestive chapter is devoted to the phenomena of muscle, nerve, gland, lymph-formation, stimulation and the action of drugs; these are considered especially in their relation to membrane processes.

In the concluding chapter the author expresses his hope that the future will see an extensive development of physiology as a pure science; he believes that biophysics and biochemistry should be cultivated side by side, in close association with the study of fundamental physical principle.

Physiology owes much to Sir William Bayliss and will honor his memory. His was a generous, many-sided, independent and creative spirit.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A SIMPLIFIED RAINPROOF VALVE FOR POROUS PORCELAIN ATMOMETERS

THERE are many ways for operating porcelain atmometers, and all are good in various peoples' hands. Workers in ecology, forestry, horticulture, etc., who employ the Livingston porous porcelain atmometers may be interested in a new modification of the mercury valve recently used by the writer. A résumé of a number of different forms of mercury valves for this instrument has been given by Thone.[1] The modification here described has been found more satisfactory for field work than any of those previously presented in the literature.

A glass closely bent J-tube with long arm about 20 cms and short arm about 4 cms long of barometer tubing (internal diameter 2 or 3 mm, external diameter 6 or 7 mm) is used to connect the porcelain piece (sphere, cylinder, etc.) with the reservoir, the bend being in the water below. The usual stoppers, one for the porcelain piece and one to fit the reservoir bottle, and provided with suitable air inlet, properly guarded to prevent the entrance of rain water, are slipped on the long arm and properly placed. The neck of the bottle must be large enough to admit the J-bend and the latter should be as narrow as possible,

[1] Thone, F., "Rainproofing valve for atmometers," *Ecology*, 5: 408–414, 1924.

so as to allow readings to be more precise than can be made with a wider neck. To the short arm of the tube is temporarily attached a 30-cm flexible rubber tube provided near its free end with a Mohr cock or similar device for closing. Both tubes are completely filled with distilled water (by means of a small funnel or thistle-tube attached to the free end of the rubber tube) and the cock is closed. Next, the porcelain piece is filled with distilled water and the free end of the J-tube is inserted, the rubber stopper being forced firmly into place in the usual way. The whole assemblage is now reversed and held upright with the J-bend below. In this manner it is lowered into the reservoir, which is nearly filled with distilled water until the short arm of the J is below the water, then a drop or two of mercury is introduced into the open end of the rubber tube, and the cock is opened. The mercury drop falls to the glass J below and forms the valve in the same general manner as in several mountings previously described. The rubber tube is now pulled off and removed, and the J-tube is lowered farther till it nearly reaches the bottom of the reservoir. The reservoir stopper borne on the tube is firmly set into place, and the operation of installing is complete except for the subsequent filling the reservoir to the index mark in its neck. The amount of water entering the reservoir for a complete reversal of the valve[2] is not more than .05 cubic centimeters.

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SPECIAL ARTICLES

THE PHOTOCHEMISTRY OF COD LIVER OIL

When Kugelmass and McQuarrie suggested recently[1] that oxidation of cod liver oil gave rise to ultra-violet radiation, the present writers were inspired to the extent of searching for other substances of biochemical or therapeutic interest which, when oxidized, might be persuaded to yield evidence of luminescence by prolonged exposure to sensitive plates. We were more disposed to this research by the encouraging reports of Steenbock[2] on the antirachitic value of radiated foodstuffs, in which he quotes the above results, presumably in support of the probability of his findings. More recently Manville[3] has quoted them in a similar connection.

[2] Harvey, E. M., "The action of the rain-correcting atmometers," *Plant World, 16*: 89–93, 1913.

[1] Kugelmass, E. N., and McQuarrie, I., Science, Vol. 60, No. 1551, Sept. 19, 1924.

[2] Nelson and Steenbock, *J. B. Chem.*, Vol. 62, p. 577, 1925.

[3] Manville, *Jour. A. M. A.*, Vol. 84, No. 19, p. 1401, 1925.

We have been unfortunate in not being able to find the substances for which we sought, nor have we been able to duplicate the results reported on cod liver oil, with satisfactory controls. We are publishing our work, however, for the use of those who may incline, as we did, toward an attractive interpretation of such findings, the further investigation of which has considerably disillusioned us.

We used Cramer instantaneous iso plates, each plate cut into four quarters just before exposure, one of which was used as a control. In certain of the experiments we bathed the plates in Nujol mineral oil, to sensitize them to ultra-violet of 2,300 to 1,900 Å U[4] checking against unsensitized parts of the same plate. We have also employed preexposure of the whole plate, before cutting, placed at one half meter from a light ruby lamp behind a ground glass screen, for ten seconds. This accomplished an exposure just sufficient to cause a slight fog with normal development; the next increment of exposure, during the experiment, was then several times more effective than the same exposure of the plate without preexposure. Except for this procedure plates were handled in complete darkness until development outside the direct beam from a safe red light.

Our experiments were performed in a light-proof box in the dark room, using Vitreosil five eighth inch test tubes as containers for the test material. Between the test tube and the plate was interposed a glass screen, with a hole or slit through which it was hoped to obtain the effects of ultra-violet radiation. Our first box, of wood, was painted on the inside with asphaltum. The tubes were thrust through holes in the cover, one half inch from the plate covered by the screen. In this box we obtained wonderful images of the slits, whether any cod liver oil was put in the tubes or not. We then transferred operations to a bright copper box, fitted with holders that facilitated manipulation, each tube and its corresponding plate being in a separate compartment. The screens used at this stage consisted of two plates of glass the edges of which were separated one fourth inch, and which were fastened together with two narrow cross

[4] Dr. Samuel Pond, of this institution, informs us that Nujol sensitized iso plates without preexposure have the same sensitivity as, or greater than, the Schumann plates, from the beginning of the gelatin absorption range (2300 Å U) to the quartz absorption range (1900 Å U). (Lyman, T., Science, July 20, 1921, p. 48.) From 2,300 to 3,500 A U the sensitivity of iso unsensitized plates is equal to or better than the Schumann. (Harrison and Hesthal, *Journ. Opt. Soc. of Am.*, 1924, Vol. 8, p. 482.) We wish to thank Dr. Pond for valuable advice throughout the photographic procedure.

strips of glass, stuck on with balsam. Again we got beautiful images of the slits, especially behind the glass cross-pieces, from radiation which we finally traced to the balsam. We therefore bored one half inch holes through glass plates two by two and one half inches and slipped these behind spring clips, inserting the plates between the screens and the side of the box. This apparatus was put in a second bright tin box (light proof), the whole wrapped in black oil cloth, and kept in the dark room in a drawer, with the door locked, all the lights being unscrewed from the sockets. Images of the holes through the screens appeared as before, equally dense from the blank tubes and the test solutions, but the necessary exposure with this apparatus was longer. Oil kept in the dark for two weeks gave the same results as that kept in diffuse light on the laboratory shelf, and exposure for one half hour to bright sunlight had no effect as compared with unradiated oil. Two different samples of oil were used, one very old sample (judged by its odor) and a fresh sample purchased at the hospital pharmacy. Both gave similar results. Nujol sensitized plates showed no greater density than unsensitized. The oil was not tested on animals for antirachitic properties.

We therefore assign all our results to black body radiation of a wave length that may penetrate quartz but not glass. Further evidence to this conclusion was obtained by conducting the experiments in a warm dark room at 40° C., where the results were much more pronounced. If the reactants were such as to raise the temperature still further (*e.g.*, neutralization of strong acid by KOH), splendid images resulted after one or two hours.

Our last experiment, No. 52 (a repetition of No. 51) was conducted as follows. Four similar quartz tubes were inserted in their holders. One was left empty, one filled with cod liver oil, one with 6 cc oil and 2 cc 40 per cent. KOH, and the fourth with the same amounts of KOH and oil but with oxygen slowly bubbling through. A plate was preexposed, cut and the quarters inserted behind glass screens with holes bored through them and left at room temperature under conditions described above for 73 hours, the plates being spaced one fourth inch from the sides of the tubes. The four sections of the plate were developed coincidentally in the same tray, and all showed equal density of background and equal density of round image. The slightly greater density that one of us thought he could see in the control we assign, if it existed, to the circumstance that the cod liver oil in the other tubes may have shielded the plates from radiation from the opposite walls of their compartments.

Previous reports have appeared on the nature of black body radiation that is transmitted by quartz but absorbed by glass, capable of affecting a photographic plate.[5]

In conclusion, though we have not perhaps demonstrated the absence of ultra-violet radiation from cod liver oil, all our positive findings of differential effects we have been able to trace to faulty procedure. Our results differ from those of Kugelmass and McQuarrie in that (1) we have been unable to confirm their positive findings, and (2) we have demonstrated the effectiveness of black body radiation in simulating such results, with poorly controlled technique.

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"RUSSELL EFFECT," NOT ULTRAVIOLET LIGHT, RESPONSIBLE FOR CHANGES PRODUCED IN THE PHOTOGRAPHIC PLATE BY ANTIRACHITIC SUBSTANCES[1]

IN a previous preliminary communication[2] the conclusion was drawn that ultraviolet light is emitted by cod liver oil and certain other substances curative of rickets when they are oxidized in alkaline media. The first method employed in the qualitative experiments reported was that of exposing a sensitive photographic plate to the substance to be tested for a period of twenty-four to forty-eight hours at a distance of a few inches and with a transparent quartz screen interposed to exclude the effects of reducing vapors. The quartz was sealed over a small aperture in the bottom of the lead plate-holder by means of two layers of adhesive tape. The photographic plate was placed in its holder with the film side down in apposition with the quartz window. This preparation was then placed directly over a beaker partially filled with the substance to be tested. The latter was alkalinized with sodium hydroxide and oxidized by a stream of oxygen or by the addition of hydrogen peroxide. All experiments were carried out completely in the dark room.

The conclusion that ultraviolet light was emitted

[5] Coblentz, W. W., Reports of the Carnegie Institution of Washington. Publ. No. 65, Part III, p. 21, 1906. Publ. No. 97, Part VII, p. 140, 1908. Quartz is shown to transmit 90 per cent. of the energy in the infra red affecting the photographic plate; furthermore, quartz itself emits at room temperature infra-red radiation in this region, with an emission maximum just within the range of photographic sensitivity.

[1] From the Department of Pediatrics, Yale University, New Haven.

[2] I. N. Kugelmass and I. McQuarrie, SCIENCE, Sept. 19, 1924.

was based upon the following facts. Visible light was never observed. When developed, most of the plates showed the presence of shadows corresponding in position and outline to the quartz window of the plate-holder. When the dry plate was exposed with the film side away from the substance, no shadowing was produced. Neither was there any fogging of the control plates. It was believed, therefore, that invisible ultraviolet light capable of passing through quartz but not through glass was given off.

Since the preliminary communication we have been forced to alter our original interpretation of the phenomenon observed. Attempts to obtain quantitative data with a more elaborate technique and with more rigid control of all the factors concerned gave such discordant results that the original methods were reexamined. After further investigation we have been forced to the conclusion that the great majority of our results can best be interpreted on the ground that they were produced by reducing vapors and not by the emission of light. The experiments failed to furnish evidence of a light emanation from oxidized substances curative of rickets. Since, in addition, we have been unable to detect the emanation of light under these conditions with the most sensitive photoelectric cell, we believe the phenomenon too difficult to isolate at present; it is probably of the nature of the so-called Russell effect.

In 1898 W. J. Russell[3] discovered that a large number of substances of most diverse character rendered a photographic plate developable. This phenomenon has since been referred to as the "Russell effect," "photechic effect," "Moser rays," "Metallic radiations," etc.—all pseudo-photographic effects.

A survey of the literature reveals that the phenomenon has been extensively observed and has been characterized by a number of properties. For example, it has been stated that the photographic plate is affected through thin sheets of gelatin, gutta percha, celluloid, collodion, tracing paper, photographic paper and porous substances but not through glass, quartz, mica and aluminum;[4] the emanation is not propagated in a rectilinear manner and can be swept along a bent tube by a current of air;[5] the effect can not be produced on a photographic plate in a current of carbon dioxide, dry air, hydrogen or in a vacuum;[6] the shadows formed are not bounded by straight lines but curve around a screen;[7] the property can be transferred from an active to an inactive body by contact; the emanation does not affect an electrical field;[8] the phenomenon occurs only in the presence of moist air and increased humidity accelerates it;[9] the effect is accentuated by previous exposure to sunlight, a moment's exposure producing activity for weeks, intense at first but gradually becoming feebler;[10] the property is lost by exposure of the substance in complete darkness; it may be restored by exposure to light and oxygen;[11] it is destroyed by heat;[12] the activity of the metals is in the order of the E.M.F. series and is promoted by cleaning the surface or merely scratching it;[13] the property common to all substances capable of fogging a photographic plate is their oxygen-absorbing capacity.[14]

The relation of the phenomenon to physiology was first studied by V. Schlaepfer,[15] who interpreted his experimental data on the basis of light emission. He found that lecithin, blood and certain organs of rabbits, when oxidized, fogged a photographic plate, the intensity of the shadow being related to the previous exposure of the animal or material to sunlight.

The active agency in this phenomenon appears to be a material substance rather than a radiation and chemical studies indicate that it is hydrogen peroxide, an intermediate product in organic oxidations.[4] All the phenomena exhibited by the active bodies can be reproduced by the solution and vapor of hydrogen peroxide itself. Russell found that a developable impression was produced on a dry plate by exposure for eighteen hours to the vapor of a solution containing only one part of hydrogen peroxide in a million parts of water,[16] thereby duplicating the action of light on a photographic plate.

The reverse reaction, wherein bubbles of oxygen were observed upon exposure of the oxidized substances to the mercury vapor quartz lamp, has not been confirmed.

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[3] W. J. Russell, Proc. Roy. Soc., London, 63, 102 (1898).

[4] W. J. Russell, *loc. cit.;* Proc. Roy. Soc., London, 80, 376 (1918).

[5] W. J. Russell, Eder's Jahrbuch 9 (1899).

[6] W. J. Russell, Proc. Roy. Soc., London, 64, 409 (1899).

[7] W. J. Russell, *Phot. J.*, 345 (1908).

[8] G. W. A. Kahlbaum, *Chem. Centralblatt*, 1905, 323.

[9] J. Blass and P. Czermak, *Physik. Z.*, 5, 36 (1904).

[10] G. LeBon, Comp. rendu. Acad. Sci., 174 (1899).

[11] E. Legrady, *Z. wiss. photog.*, 60, 1908.

[12] W. J. Russell, Proc. Roy. Soc., London, 64, 409 (1899); Luppo-Cramer, Phot. Korr., 1902, 563.

[13] *Ibid.*

[14] Kugelmass and I. McQuarrie, *loc. cit.*

[15] V. Schlaepfer, Pfluger's Archiv. f. Physiol., 561 (1905).

[16] W. J. Russell, *loc. cit.;* O. Dony, *Chem. Centralblatt*, 1908, 569.

THE AMERICAN CHEMICAL SOCIETY

DIVISION OF CHEMICAL EDUCATION

W. A. Noyes, *chairman*
B. S. Hopkins, *secretary*

Educating the public in the use of the metric system: HARVEY A. NEVILLE. All countries except Great Britain and the United States have adopted the metric system of measurement. When this step is taken here, it will be the duty of the educational system of the country to familiarize the public with the usage and advantages of metric units. For this purpose methods of visual instruction are suggested. The convenience of decimal relations and the interrelation of the fundamental units are emphasized. The metric equivalents of common quantities are graphically shown. Some practical conveniences of metric units are pointed out, and the economy of time and effort now dissipated in teaching several different systems of measurement is discussed.

Ethylene: F. B. ARENTZ. Ethylene gas, discovered in 1795 by four Dutch chemists, did not come into prominence until the World War. Its first use was in the manufacture of mustard gas, but now its use for cutting and welding, coloring of citrus fruits, as an anesthetic and in chemical synthesis is becoming more general. Ethylene is made by passing ethyl alcohol vapor over a heated catalyst, condensing out the water formed, and compressing the pure gas into steel cylinders.

Some angles in the articulation of high school and college chemistry: CHARLES E. COATES. A discussion of the attitude of the college teacher and the nature of college requirements relative to this problem. The different purposes of various first-year courses in college chemistry and how these purposes can best be accomplished. The time in the high school course in which chemistry is given. Difference in qualifications of high school teachers of chemistry with regard to scholarship and teaching ability. The difference in qualifications of first-year teachers in college chemistry in regard to scholarship and teaching ability. The degree of maturity of high school students. The equipment of high school laboratories. Is high school chemistry a real help to the college student in chemistry, and if so, to what degree and why?

A tested method of teaching the history of chemistry: LYMAN C. NEWELL. Instruction in the history of chemistry is handicapped by the student's lack of historical background and his incomplete knowledge of chemistry. Attempts to give a consecutive or detailed course are doomed to failure. An experience of twenty-five years has convinced me that the only method suitable for a mixed class of beginners must possess certain features: (1) It must be built around the personality and specific contributions of prominent chemists, (2) it must be illustrated by portraits, books and memorabilia, (3) it should be supplemented by two kinds of papers prepared by students, *viz.*, short papers at frequent intervals and one or more longer papers requiring special reading.

Systematic treatment of first-year chemistry: P. M. GLASOE. Approach the subject through familiar channels. Do not swamp the student with new definitions and new vocabulary from the start. Have student name a list of all the metals and non-metals he knows from everyday life. Carry the process forward by having him arrange the elements as found in a table of atomic weights in the order of their weights. Fifteen or twenty metals with half a dozen non-metals constitute a year's work. Arrange first two series, Li–Ne and Na–A, so as to show grouping. Study, by means of these series, the change of properties from metallic to non-metallic, positive to negative basis to acid. On the same basis take up chemical affinity, valence, structural formulas; acids, their derivation and structural formulas, bases, their derivation and structure; salts, their structural formulas and relative stability; the derivation and properties of the anhydrides of both bases and acids. Amphoterism is a natural deduction. Elements are studied in the order of their occurrence in the groups of the Periodic System.

The art of lecture table demonstrating: HERBERT F. DAVIDSON. Lecture table demonstrations are worth while because they make the subject concrete. Chemistry as usually taught is, to many students, a very abstract thing, but well-chosen, deftly performed experiments can make the subject very real to such students. Demonstrations should not be performed simply because they are spectacular, but because they teach a chemical lesson. The building of apparatus which above all should be simple and capable of expeditious exhibition, gives the teacher himself the kind of mental stimulation needed by those who teach the general chemistry. It is better to show no experiments on the lecture table than to have any appreciable percentage of failures. A number of experiments will be performed to illustrate the principles discussed.

Correlation of high school and college chemistry: LEROY L. SUTHERLAND. A discussion of the true function of a high school chemistry course as to purpose and scope. A plea that colleges and universities exercise greater caution in accrediting the science work of secondary schools. An exposition of the harm done to both chemistry and the individual student, when on entering freshman chemistry, he is given no recognition whatsoever for work done in his high school course, but told to "Forget all you have learned—we will now teach you correctly." A claim that the study and teaching of chemistry should be a progressive growth, and not a planting of seed which as they begin to sprout are ruthlessly torn up and cast aside on the dump-pile to be replaced by more seed. This represents lost motion. We must see to it that the secondary schools plant the right kind of seed, and then build to but not destroy their work.

Teaching the growth of chemistry in industry by the

use of maps: Louis W. Mattern. From reports compiled by Professor Charles E. Munroe, expert agent in charge of "Chemicals and Allied Products" at the U. S. censuses 1900–1905–1910, several charts were prepared which he used during the course of an address, published in the January, 1925, issue of the *Journal of Chemical Education,* to show the growth of several chemical industries and the need of their extension into unoccupied fields. These charts are very instructive, so it has been suggested that the large body of important census statistics of chemical industries since 1900 could be used in producing a system of charts, by means of suitable characters on maps of the United States, which would clearly visualize the growth of chemistry in industry and the vast areas of latent resources which challenge chemistry to greater service. Such maps would prove most useful to teachers. Acting on the belief of the importance of this work, the author has conferred with Mr. William W. Stuart, director of the census, on the feasibility of this matter and who expressed his desire to furnish maps of intervening censuses.

The problem of high school chemistry: Guy Clinton. The three principal factors recognized are matter, arrangement and method. The paper is restricted to the discussion of the latter two. One fundamental principle which determines arrangement is that matter should be presented in a progressive order, so that that which follows may not presume knowledge beyond what the preceding exercises give opportunity to learn. It is considered preferable to build a course around laboratory experiments rather than to take it from a text-book. Experiments should be grouped about principles rather than principles about experiments. The language of chemistry should receive the particular attention of teachers.

Museum experiments: R. A. Baker. Any reaction which requires considerable time for completion, or which is of such a nature that its course is automatically recorded, may be utilized as a "museum experiment." The set-ups may be displayed long enough to attract general attention, and when properly placarded, stimulate interest and profitable discussion among students. A number of appropriate experiments are described.

The present status of the ionization theory: James Kendall. The original ionization theory, as formulated by Arrhenius, is unable to account for the most important type of all conducting solutions—strong electrolytes in water. These do not follow Ostwald's dilution law, but do conform approximately, nevertheless, to the solubility product principle. It may be deduced from this that the stumbling-block is connected in some way with the undissociated molecule in solution. Recent research, indeed, demonstrates that the Arrhenius conception of kinetic equilibrium between undissociated and ionized solute is incorrect. The extension of the ideas of the Braggs on crystal structure and of Lewis and Langmuir on atomic structure to solution leads to the conclusion that the undissociated molecule is practically non-existent, and that at high dilutions electrostatic forces between oppositely charged ions are the prime factors to be considered. At greater concentrations, interactions between solvent and solute must be taken into account, and rules regarding such interactions have been qualitatively established. The collapse of the theory of Ghosh discredited "complete ionization" temporarily, but the more rigorous equations of Debye and Huckel are fully in accord with experimental data. Some points of difficulty still remain, but the rapid advances made in the last few years inspire the hope that the field will be entirely cleared up in the near future.

Use of charts, motion pictures and other aids in the teaching of elementary organic chemistry: Alexander Lowy. A number of charts, diagrams, such as "Products from a barrel of oil," "Products from a hundred tons of coal," "Organic type formulas," "Organic chemical transformations," "Petroleum refining," etc., will be shown. The use of motion pictures entitled "The story of petroleum" (4 reels, distributed by the Bureau of Mines) and "By-product coking" (2 reels, distributed by the Koppers Company, Pittsburgh) will be emphasized. Saving time at lectures by using colored crayons will be illustrated.

Minimum essentials: "Teach—test—reteach": Rachel E. Anderson. The determination of a definite course of study to fit the existing needs of a high school where college and non-college preparatory students are taught in the same class. The adoption of definite minimum essentials to be mastered by all students; the effective and rapid measurement of them to determine whether reteaching is necessary for the individual or the class collectively. The experiment has proved the effectiveness of teaching for mastery, rather than for distribution along a normal curve. In fact the application of the method of "Teach—test—reteach" has developed a mastery of fundamental principles that has made the curve of distribution top-heavy on the positive side. The plan breeds a closer correlation between laboratory and text-book assignment and the use of reference books. Furthermore, the plan is not complete until chemistry is built into everyday processes. Slosson's "Creative Chemistry" is read and the rather pleasant game of one hundred "false and true" questions measure the results. Chemistry has increased in popularity and there has been a marked decrease in the number of failures.

Teaching principles of electrodeposition: W. Blum. The importance of potential relations, and especially of single potentials during deposition, is emphasized. Potential changes involved in polarization can be most simply explained in terms of the changes in "effective metal ion concentration." From polarization curves it is often possible to predict the direction of the effect of different variables upon the distribution and crystalline structure of the deposited metals.